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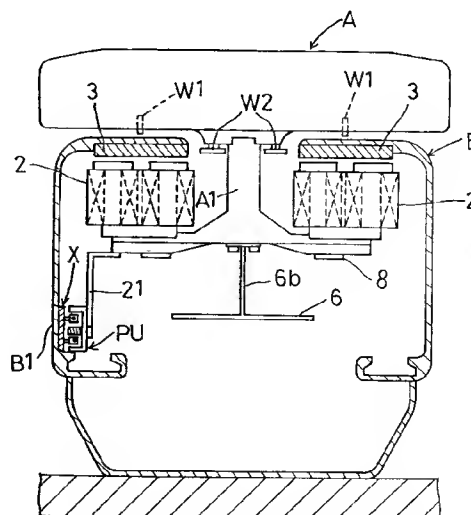
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(54) **Magnetic levitation transport system.**

(57) A magnetic levitation transport system includes magnetic levitation vehicles (A) each driven by a linear motor to run along a track (B). Induction lines (L) extend through predetermined blocks of the running track to transmit a high frequency sine-wave current. Each vehicle includes electromagnets (2) to attract levitating magnetic members (3) extending along the running track, a pickup coil (PU) resonant with a frequency of the induction lines (L) to generate an electromotive force, and a battery (10) chargeable by the pickup coil (PU). The electromagnets receive power from the pickup coil and/or the battery.

FIG. 1



EP 0 580 107 A1

## BACKGROUND OF THE INVENTION

### 1. FIELD OF THE INVENTION

This invention relates to magnetic levitation transport systems, and more particularly to a magnetic levitation transport system having vehicles lifted by a magnetic force generating device which attracts magnetic members extending along a running track, and propelled by a linear motor to transport loads.

### 2. DESCRIPTION OF THE RELATED ART

A conventional magnetic levitation transport system will be described with reference to Figs. 21 through 23. This system includes a load carrying vehicle A lifted and propelled along a guide rail B defining a running track in a cleanroom. The vehicle A is magnetically levitated, and driven by a linear motor to move from one loading and unloading station ST to another.

The guide rail B includes a main body B1 formed by extrusion molding a non-magnetic material such as aluminum. The main body B1 is in the shape of a square tube, with an upper surface defining an opening extending longitudinally of the rail B. The main body B1 has magnetic members 3 attached to lower sides of the upper surface. The magnetic members 3 extend along the upper opening and are spaced from each other transversely of the main body B1. The vehicle A has levitating electromagnets 2 disposed under and attracting the magnetic members 3, respectively. The vehicle A is movable along the guide rail B, with a main body A1 of the vehicle A disposed inside the main body B1 of the rail B. The guide rail B further includes primary coils 5 of a linear motor mounted in the bottom thereof.

As shown in Fig. 23, the primary coils 5 are arranged at intervals along the guide rail B to decelerate and stop the vehicle A at each station ST and to start and accelerate the vehicle A.

The main body B1 of the guide rail B contains stopping electromagnets 7 in positions opposed to each station ST. These electromagnets 7 attract, from below, stopping magnetic members 8 attached to the vehicle A to maintain the vehicle A at a standstill. The magnetic members 8 are arranged in the front and rear and right and left corners of the vehicle A. Thus, four electromagnets 7 are arranged in place to act on the respective magnetic members 8.

The vehicle A includes a flat load supporting deck 15 disposed on top. The levitating electromagnets 2 are arranged in the front and rear and right and left corners of the vehicle A to act as magnetic force generating means for attracting the

levitating magnetic members 3 from below. The vehicle A further includes a secondary conductor 6 formed of a non-magnetic material such as aluminum to act on the primary coils 5 of the guide rail B. The secondary conductor 6 is supported in horizontal posture in a lower region of the vehicle A, with a transversely middle position thereof attached to a prop 6b depending from a transversely middle position of the main body A1 of the vehicle A. The guide rail B supports magnetic plates 6c arranged only in positions where the primary coils 5 are present. The secondary conductor 6 is movable through spaces defined between the magnetic plates 6c and upper surfaces of the primary coils 5. Thrust is applied to the vehicle A when the secondary conductor 6 passes through these spaces.

The levitating electromagnets 2 are electrified by a battery 10 mounted on the main body A1 of the vehicle A. As a result, upper surfaces of the levitating electromagnets 2 are maintained within a predetermined range of distance from lower surfaces of the levitating magnetic members 3 based on information provided by gap sensors (not shown). The stopping electromagnets 7 are electrified only when maintaining the vehicle A at a standstill at the station ST.

In Fig. 21, reference R1 denotes guide rollers for maintaining vertical spacing between the levitating electromagnets 2 and magnetic members 3 when the electromagnets 2 are de-electrified. Reference R2 denotes guide rollers for maintaining a smaller transverse spacing between the vehicle A and guide rail B than a predetermined value, to prevent the vehicle A from colliding with inner lateral surfaces of the levitating magnetic members 3.

The known magnetic levitation transport system has the disadvantage of having to change or charge the battery 10 every five to six hours, which impairs operating efficiency of the vehicle A. Moreover, the battery 10 must be subjected to maintenance periodically.

In order to overcome these disadvantages, it is conceivable to lay along the guide rail B a power rail formed of a conductive material such as copper, and provide the vehicle A with a collector to contact and receive power from the power rail to charge the battery 10. With such a construction, however, maintenance is imperative since the power rail and collector become worn through contact. Further, this construction would produce wastes such as abrasion dust, and cannot therefore be used in a cleanroom.

### SUMMARY OF THE INVENTION

An object of the present invention is to overcome the disadvantages of the prior art noted

above, and provide a magnetic levitation transport system which does not require change of batteries over a long period of time, thereby to secure improved operating efficiency, and which may be used in a cleanroom.

The above object is fulfilled, according to the present invention, by a magnetic levitation transport system comprising a magnetic levitation vehicle, lines extending through predetermined blocks of a running track of the vehicle to transmit a high frequency sine-wave current therethrough, wherein the vehicle includes a levitating magnetic force generating device to attract levitating magnetic members extending along the running track, a pickup coil resonant with a frequency of the lines to generate an electromotive force, and a battery chargeable by the pickup coil, the levitating magnetic force generating device receiving power from the pickup coil and/or the battery.

With the above construction, an electromotive force is generated in the pickup coil when power (alternating current) is supplied to the lines extending through the predetermined blocks of the track. As a result, the vehicle receives power in a non-contact mode while running through these blocks of the track, with the battery charged, and power supplied to the levitating magnetic force generating device. When the vehicle runs along the track other than the predetermined blocks, the levitating magnetic force generating device receives power from the battery.

As noted above, the present invention allows an electromotive force to be generated in the pickup coil by supplying power (alternating current) to the lines extending through the predetermined blocks of the track. The vehicle may receive power in a non-contact mode and the battery may be charged as well while the vehicle runs through these blocks of the track. Consequently, it is no longer necessary to change the battery every five to six hours as is the case with the prior art. This feature improves operating efficiency and drastically reduces the time consumed in maintenance since the battery need not be changed for at least one year. Power may be supplied to the vehicle regardless of its running direction.

The levitating magnetic force generating device may include electromagnets and permanent magnets. This provides the advantage of allowing the electromagnets to be excited with reduced currents and to be compact.

According to the present invention, a vehicle propelled along a guide rail may include a magnetic force generating device having electromagnets and permanent magnets for generating magnetic forces with levitating magnetic members included in the guide rail to levitate the vehicle, and a control device for controlling the magnetic forces,

in which the electromagnets and permanent magnets are arranged opposite the levitating magnetic members, respectively.

With this construction in which the electromagnets and permanent magnets constituting the magnetic force generating device mounted on the vehicle are arranged opposite the levitating magnetic members, respectively, the permanent magnets are not incorporated into magnetic circuits of the electromagnets, thereby avoiding increased magnetic resistance in the magnetic circuits.

Thus, this construction avoids reduced efficiency of the electromagnets occurring where the permanent magnets are joined to intermediate positions or opposite ends of yokes each supporting a pair of electromagnets.

Each of the permanent magnets may be formed cylindrical to surround one of the electromagnets.

With each cylindrical permanent magnet surrounding one of the electromagnets, large areas are secured opposite the levitating magnetic members to produce sufficient magnetic forces, which allow the entire magnetic force generating device to be compact.

An adjusting device may be provided for adjusting a relative position between the permanent magnets and electromagnets in directions toward and away from the levitating magnetic members.

With the permanent magnets and electromagnets adjustable relative to each other in directions toward and away from the levitating magnetic members, a relative position may be selected according to the weight of a load to enable diminishment of the exciting currents supplied to the electromagnets. For example, where the vehicle has permanent magnets capable of generating sufficient magnetic forces to cope with a heavy load placed on the vehicle, the permanent magnets may be moved relative to the electromagnets away from the levitating magnetic members, when the load is light, to diminish the attractive forces acting between the permanent magnets and magnetic members. In this way, a rough adjustment of the necessary attractive forces may be carried out by varying the relative position between the permanent magnets and electromagnets according to the weight of the load. This enables a reduced range of adjustment of the necessary attractive forces produced by the electromagnets, which in turn realizes diminished exciting currents supplied to the electromagnets.

More advantageously, the adjusting device may be automatically operable to move the permanent magnets relative to the electromagnets the closer to the levitating magnetic members with the heavier load placed on the vehicle.

The vehicle may further include a gap detecting device for detecting a gap between the vehicle and guide rail, the control device being operable to control the magnetic forces such that a value detected by the gap detecting device become a predetermined value.

That is, the magnetic forces of the levitating magnetic members are controllable such that a gap between the vehicle and guide rail, e.g. a detection value of the gap detecting device for detecting the gap between the vehicle and guide rail, correspond to with a predetermined value. In this case, even when a load has an increased weight, the relative position between the permanent magnets and electromagnets is varied to maintain the gap constant and to check an increase in the exciting currents supplied to the electromagnets.

Further, the vehicle may include a current detecting device for detecting the exciting currents supplied to the electromagnets, the control device being operable, in response to detection information received from the current detecting device, to control the magnetic forces such that the exciting currents become zero steady level.

With this construction, the magnetic forces are controllable based on detection information received from the current detecting device for detecting the exciting currents supplied to the electromagnets to bring the exciting currents to zero steady level. In this case, even when a load has a varied weight, the relative position between the permanent magnets and electromagnets is varied to bring the exciting currents close to zero steady level without substantially varying the gap between the vehicle and guide rail.

Consequently, in the magnetic levitation transport system in which permanent magnets are used alongside the electromagnets in the magnetic force generating device of the vehicle in order to diminish the exciting currents supplied to the electromagnets, the exciting currents are diminished while maintaining the gap between the vehicle and guide rail in a proper range despite variations in the weight of the load.

The levitating magnetic members may be magnetized substantially at right angles to a running direction of the vehicle, and the vehicle may include a control device for controlling magnetic forces of the electromagnets constituting the magnetic force generating device, the control device being operable to control electrification of the electromagnets such that magnetic forces acting between the electromagnets and levitating magnetic members be switched between attractive forces and repulsive forces.

With this construction, since the levitating magnetic members are magnetized substantially at

right angles to a running direction of the vehicle, not only attractive forces but also repulsive forces may be generated between the electromagnets on the vehicle and the levitating magnetic members.

That is, with the control device operable to control electrification of the electromagnets (e.g. to switch polarity of the exciting currents), the magnetic forces acting between the electromagnets and levitating magnetic members may be switched between attractive forces and repulsive forces. When, for example, the electromagnets and levitating magnetic members have moved too close to each other, the magnetic forces acting therebetween are switched to repulsive forces for a very brief time. This prevents the electromagnets and levitating magnetic members from moving closer to each other by inertia, and promptly restores a proper gap therebetween.

This construction effectively checks and quickly damps vertical vibrations of the vehicle, compared with the magnetic forces acting between the electromagnets and levitating magnetic members being used only as attractive forces, and separation thereof being dependent on a natural descent which is made possible by weakening the attractive forces.

In another aspect of the present invention, a magnetic levitation transport system comprises a magnetic force generating device for levitating the vehicle above the guide rail, a levitated state detecting device for detecting a difference between a predetermined proper levitated state and an actual levitated state provided by the levitating force of the magnetic force generating device, a levitation control device operable in response to detection information received from the levitated state detecting device to control the levitating force of the magnetic force generating device, thereby to maintain the predetermined proper levitated state, a propelling force generating device for applying a forward or backward propelling force to the vehicle along the guide rail, and a propelling force control device for controlling the propelling force generating device.

With this construction, the magnetic force generating device lifts the vehicle out of contact with the guide rail, and the propelling force generating device such as a linear induction motor (LIM) propels the vehicle along the guide rail. In this way, the vehicle may transport a load efficiently and smoothly from one station to another.

Advantageously, this magnetic levitation transport system may further comprise a state value detecting device for detecting a state value variable with variations in weight of the vehicle, the propelling force control device being operable in response to detection information received from the state value detecting device to control the forward

or backward propelling force.

With this construction, the levitation control device controls the magnetic force generating device based on detection information from the levitated state detecting device, to maintain the vehicle in a proper levitated state above the guide rail. At the same time, the propelling force control device controls the forward or backward propelling force based on detection information from the state value detecting device which is variable with the weight of the vehicle including the load.

The levitated state detecting device may be operable to detect a difference between a predetermined proper gap and an actual gap between the vehicle and guide rail, the levitation control device may be operable to control the levitating force of the magnetic force generating device to bring the actual gap to the proper gap, and the state value detecting device may be operable to detect the levitating force of the magnetic force generating device.

With this construction, the levitation control device controls the levitating force of the magnetic force generating device, so that the gap between the vehicle and guide rail detected by the levitated state detecting device become a predetermined proper gap. That is, the levitating force of the magnetic force generating device is varied according to the weight of the vehicle including a load. The levitated state detecting device detects this levitating force, and the propelling force control device controls the forward or backward propelling force based on the detection information from the state value detecting device. The levitating force of the magnetic force generating device may be detected from energy supplied to the magnetic force generating device, e.g. the exciting currents supplied to the electromagnets where levitating forces are generated by the magnetic forces of the electromagnets.

This construction provides the advantage that the forward or backward propelling force may be controlled with nicety according to an actual weight of the vehicle including a load.

The levitated state detecting device may be operable to detect a difference between a predetermined proper value and energy supplied to the levitating magnetic force generating device and to detect variations in the gap between the vehicle and guide rail, the levitation control device may be operable to control the levitating force of the magnetic force generating device to bring the energy supplied to the magnetic force generating device to the predetermined proper value in the absence of variations in the gap, and the state value detecting device may be operable to detect the gap.

With this construction, the levitation control device is operable, in response to a difference be-

tween the predetermined proper value and energy supplied to the levitating magnetic force generating device and variations in the gap between the vehicle and guide rail as detected by the levitated state detecting device, to control the levitating force of the magnetic force generating device such that the energy supplied to the magnetic force generating device be the predetermined proper value in the absence of variations in the gap (in a steady state). Where, for example, levitating forces are generated by the magnetic forces of electromagnets, the exciting currents for the electromagnets are controlled to be a predetermined proper value in a steady state. By using permanent magnets as well, the exciting currents for the electromagnets may be reduced to zero in a steady state.

In this case, the levitating force of the magnetic force generating device is varied for a transient period according to the weight of the vehicle including a load, to vary and maintain the gap to balance the weight. The state value detecting device detects this gap, and the propelling force control device controls the forward or backward propelling force based on detection information from the state value detecting device.

Where, for example, the propelling force generating device is a linear induction motor (LIM), the control of the forward or backward propelling force is carried out by varying an effective voltage applied to primary coils according to the weight. In a stopping control, a transfer function gain is varied according to the weight when the backward propelling force is subjected to feedback control based on a distance to a stopping position and speed of the vehicle.

A state value corresponding to a weight may be obtained by utilizing a device required for the levitation control. That is, the state value detecting device may be used also as part of the levitated state detecting device for detecting the gap between the vehicle and guide rail.

The foregoing and other objects, features and advantages of the invention will be apparent from the following more particular description of preferred embodiments of the invention, as illustrated in the accompanying drawings.

#### BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a front view of a magnetic levitation transport system according to the present invention;

Fig. 2 is a sectional side view of the magnetic levitation transport system;

Fig. 3 is a schematic plan view showing a layout of a guide rail in the magnetic levitation transport system;

Fig. 4 is a sectional view of a pickup unit in the magnetic levitation transport system;

Figs. 5 (a), (b) and (c) are a plan view, a front view and a side view of the pickup unit, respectively;

Fig. 6 is a diagram of circuitry in the magnetic levitation transport system;

Fig. 7 is a graph of secondary frequency to electromotive force characteristics of the magnetic levitation transport system;

Fig. 8 is a plan view of a vehicle having a magnetic force generating device in another embodiment of the invention;

Fig. 9 is a layout plan view showing a portion of the magnetic levitation transport system of Fig. 8;

Fig. 10 is a sectional view of the vehicle and guide rail as seen in a direction of movement of the vehicle;

Fig. 11 is a side view showing construction of the vehicle and guide rail of Fig. 10;

Fig. 12 is a block diagram showing controls effected by a control device of the vehicle shown in Fig. 8;

Figs. 13 (a), (b), (c) and (d) are schematic views of modified magnetic force generating devices, respectively;

Fig. 14 is a sectional view of a vehicle and a guide rail in a further embodiment of the invention;

Fig. 15 is a side view showing construction of the vehicle and guide rail of Fig. 14;

Fig. 16 is a block diagram showing controls effected by a control device of the vehicle shown in Fig. 14;

Fig. 17 is a block diagram showing control of exciting currents supplied to electromagnets shown in Fig. 14;

Fig. 18 is a block diagram of a principal portion of a magnetic levitation transport system in a further embodiment of the invention;

Fig. 19 is a sectional view of a vehicle and a guide rail in the magnetic levitation transport system shown in Fig. 18;

Fig. 20 is a side view showing construction of the vehicle and guide rail shown in Fig. 18;

Fig. 21 is a front view of a conventional magnetic levitation transport system;

Fig. 22 is a sectional side view of the conventional magnetic levitation transport system; and Fig. 23 is a schematic plan view showing a layout of a guide rail in the conventional magnetic levitation transport system.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Magnetic levitation transport systems according to the present invention will be described in detail hereinafter with reference to the drawings.

Like reference numerals are used to identify like parts in Figs. 21 through 23 showing the prior art, which will not be described again.

Referring to Figs. 1 through 3, a guide rail B has induction line units X extending along inner walls of predetermined blocks thereof. As shown in enlargement in Fig. 4, each induction line unit X includes an elongate plate-like bracket 14 formed of aluminum which is a magnetic field shielding material. The bracket 14 extends along the guide rail B, and supports pairs of upper and lower horizontal hangers 14a arranged at predetermined intervals along the guide rail B. Each hanger 14a supports a plastic duct 14b attached to a distal end thereof and extending along the guide rail B. The duct 14b contains an induction line L connected to a power source assembly P disposed outside the guide rail B as shown in Fig. 2. The induction line L is a strand wire (hereinafter called a litz wire) formed of thin insulated wires, and covered with an insulator such as a plastic material. The above-mentioned predetermined blocks are straight portions of the guide rail B, for example.

The main body A1 of the vehicle A has a pickup unit PU disposed in a lower position thereof opposed to the bracket 14 supporting the induction line L. As shown in Fig. 5, the pickup unit PU includes a ferrite 18 acting as a magnetic member having an E-shaped section and elongated along the guide rail B, a pickup coil 19 formed of a litz wire wound with 10 to 20 turns around upper and lower surfaces of a middle projection 18A of the ferrite 18, and plate-like lugs 20 attached in vertical posture to opposite ends of one side of the ferrite 18. Projections 18A, 18B and 18C of the ferrite 18 have distal ends 18D extending vertically and inwardly. As shown in Fig. 5 (c), each lug 20 defines a vertically elongated mounting bore 20A having semicircular opposite ends. The lugs 20 are connected to a pair of supports 21 projecting from the vehicle A toward the guide rail B, by bolts 22A extending through mounting bores 20A and 21A. The ferrite 18 of the pickup unit PU is vertically adjusted so that, when the vehicle A is lifted to a predetermined levitation level, the center L of the ferrite 18 be halfway between each pair of ducts 14b of the induction line unit X and perpendicular to the bracket 14. The pickup unit PU is turned as indicated by arrows and vertically adjusted to place the upper and lower projections 18B and 18C of the ferrite 18 above and below the pair of ducts 14b of the

induction line unit X, respectively. Then, nuts 22B are tightened to fix the pickup unit PU in position. With the pickup unit PU fixed in position, each duct 14b, as shown in Fig. 4, is disposed substantially halfway between the pickup coil 19 on the ferrite 18 and the upper or lower projection 18B or 18C. The pickup unit PU is constructed such that the ferrite 18 and pickup coil 19 do not contact the ducts 14b or bracket 14 when the vehicle A is not lifted.

As shown in Fig. 2, the vehicle A has, mounted on an upper surface of the main body A1, a power receiving unit 23 for receiving an electromotive force generated in the pickup coil 19, a battery 10 for supplying power to electromagnets 2 acting as levitating magnetic force generating means, and a control device 9 for controlling power supply to the electromagnets 2. The control device 9 confirms a levitation level of the vehicle A based on detection signals received from gap sensors (not shown), produces a signal for controlling electrification of the levitating electromagnets 2, and outputs this signal to a power circuit 25 included in the power receiving unit 23 and connected to the electromagnets 2 as shown in Fig. 6.

Detailed circuit constructions of the power source assembly P and power receiving unit 23 will be described with reference to Fig. 6.

The power source assembly P includes a 200V three-phase AC source 41, a converter 42, a sine-wave resonance inverter 43, and a transistor 44 and a diode 45 for protection against over-current. The converter 42 includes diodes 46 for full-wave rectification, coils 47 acting as filters, a capacitor 48, a resistor 49, and a transistor 50 for short-circuiting the resistor 49. The sine-wave resonance inverter 43 includes transistors 51 and 52 driven by rectangular wave signals generated alternately as shown in Fig. 6, a current limiting coil 53, a current supplying coil 54 connected to the transistors 51 and 52, and a capacitor 55 forming a parallel resonance circuit with the induction line L. Transistor control devices are omitted from the illustration.

The power receiving unit 23 is connected parallel to the pickup coil 19. The power receiving unit 23 includes a capacitor 31 forming a circuit resonant with a frequency of the pickup coil 19 and induction line L. A rectifying diode 32 is connected parallel to the capacitor 31. A stabilizing source circuit 33 is connected to the diode 32 to control output of the diode 32 to a predetermined DC voltage. The power circuit 25 is connected to the stabilizing source circuit 33 through a diode 34 to adjust electrification of the levitating electromagnets 2. The stabilizing source circuit 33 is connected to the positive electrode of the battery 10 through a diode 26. The positive electrode of the battery 10 is connected also to the power circuit 25

through two diodes 27 forming a high-value priority circuit with the diode 34. The levitating electromagnets 2 are connected to the power circuit 25. The stabilizing source circuit 33 includes a current limiting coil 35, an output adjusting transistor 36, a diode 37 acting as a filter, and a capacitor 38. A transistor control device is omitted from the illustration. The diodes 34, 36 and 27 have the same characteristic.

Operations of the power source assembly P, induction line L and vehicle A will be described next.

The 200V three-phase alternating current outputted from the AC source 41 is changed to a direct current by the converter 42. This current is changed to a high frequency wave such as a 10kHz sine wave by the sine-wave resonance inverter 43 and supplied to the induction line L. The control device 9 confirms a levitation level of the vehicle A based on detection signals received from the gap sensors, and outputs an electrification control signal to the power circuit 25 in the power receiving unit 23 to place the vehicle A at a predetermined levitation level.

In the straight portions of the guide rail B where the induction line L is laid, a magnetic flux generated in the induction line L generates an electromotive force in the pickup coil 19 of the vehicle A resonant with the frequency of the induction line L. An alternating current generated by this electromotive force is rectified by the diode 32 in the power receiving unit 23, controlled to a predetermined DC voltage by the stabilizing source circuit 33, and supplied to the levitating electromagnets 2 through the power circuit 25 according to the electrification control signal inputted thereto from the control device 22, thereby lifting the vehicle A. The stabilizing source circuit 33 acts also to charge the battery 10. In the straight portion of the guide rail B, the high-value priority circuit formed of the diodes 34 and 27 is operable to pass no current from the battery 10 to the power circuit 25. In this state, the vehicle A is propelled by the primary coils 5 provided at stations ST.

In curved portions of the guide rail B having no induction line L, no electromotive force is generated in the pickup coil 19 of the vehicle A, and zero voltage is outputted from the stabilizing source circuit 33. In the curved portions, power is supplied from the battery 10 to the power circuit 25 and, according to the electrification control signal inputted from the control device 22, the power circuit 25 electrifies the levitating electromagnets 2 to lift the vehicle A.

As described above, the vehicle A receives power supply in a non-contact mode, with the battery 10 being charged as well, while transporting a load along the guide rail B. It is unnecessary to

change the battery every five or six hours, which assures improved operating efficiency. Maintenance of the battery need not be carried out for one year or more, thereby drastically reducing maintenance time. Power may be supplied to the vehicle A regardless of its moving direction.

Since power is supplied in a non-contact mode, this system does not produce dust as produced through contact between a power supply rail and a collector in the prior art. Thus, the transport system according to the present invention may be used in a cleanroom.

As noted hereinbefore, the E-shaped ferrite 18 is fixed with the opening side thereof opposed to one side of the bracket 14, and with the pickup coil 19 placed halfway between two tiers of the induction line L. Consequently, as shown in Fig. 4, the pickup coil 19 lies in a position of maximum flux density produced by the induction line L, whereby a maximum electromotive force is induced for efficient power supply.

Since the induction line units X are provided only in straight portions of the guide rail B, the pickup unit PU is free from contact with the induction lines L. The pickup unit PU could contact the induction lines L if the latter were provided in curved portions also. Thus, the ferrite 18 of the pickup unit PU may have a freely selected length. However, an induction line unit X may be provided in each gently curved portion to extend continuously along the guide rail B.

Since the induction line L is longer than the pickup coil 19, the induction line L has a substantially constant primary inductance. Further, since the capacitor 55 of the power source assembly P and induction line L form a resonance circuit, the induction line L may receive a high frequency, sine-wave primary current in a substantially constant, large amount. With the pickup coil 19 forming a secondary resonance circuit, as shown in Fig. 7, a high secondary voltage (1000 to 2000V in the graph) is generated at resonance frequency  $f_0$ . A secondary voltage exceeding a predetermined value (300V in the graph) may be generated in a frequency range  $f_1$ - $f_2$  even if levitation of the vehicle A vertically displaces the pickup coil 19 with respect to the induction line L, even if the frequency of the induction line L varies a little, and even if the secondary resonance frequency varies a little from the frequency of the induction line L. This assures a steady supply of a large amount of power. The vertical adjustment noted hereinbefore may be carried out roughly in order to promote operating efficiency and facilitate manufacture.

The litz wires covered with an insulating material are used as the induction line L and pickup coil 19, which present no exposure of the conductive parts, thereby promoting safety. The absence

of sparks eliminates risks of fire. Thus, this transport system may be used in an explosion-proof area. Since the induction line L receives a sine wave, no higher harmonics are generated and hence no radio noise.

In the foregoing embodiment, one duct 14b contains one induction line L. Instead, one duct 14b may contain two or more induction lines L to boost power. An inverter may be connected to the stabilizing source circuit 33 in the power receiving unit 23 to collect a commercial frequency alternating current. This current may be used to drive a loading and unloading motor mounted on the load supporting deck 15 of the vehicle A.

Another embodiment will be described hereinafter.

An unmanned transport system in this embodiment is operable automatically to transport loads such as semiconductor wafers in a cleanroom. As shown in Fig. 9, the transport system includes a guide rail B extending along a running track of vehicles A. Each vehicle A is magnetically levitated, and driven by a linear motor to run along the guide rail B.

As shown in Figs. 10 and 11, the guide rail B has levitating magnetic members 3 attached to lower surfaces of upper horizontal flanges thereof to be attracted by magnetic force generating devices 2 of each vehicle A. The magnetic force generating devices 2 are mounted on a lower frame 1 of the vehicle A and distributed to four, front and rear and right and left, corners of the vehicle A. Each magnetic force generating device 2 includes permanent magnets 2a and electromagnets 2b, and is opposed to one of the levitating magnetic members 3.

The electromagnets 2b share a U-shaped yoke 2b1 having a pair of end faces opposed to one of the levitating magnetic members 3, and two coils 2b2 connected in series and wound around two bobbins mounted on the yoke 2b1. The permanent magnets 2a are formed cylindrical to surround the coils 2b2, respectively. Thus, as shown in plan in Fig. 8, each end face of the yoke 2b1, coil 2b2 and permanent magnet 2a are arranged concentrically. Each pair of permanent magnets 2a is rigidly attached to a frame 2a1, and movable vertically (perpendicular to the sheet of Fig. 11) by a mounting structure described hereinafter.

One of the permanent magnets 2a forming a pair has an end face opposed to the levitating magnetic member 3 (i.e. upper end) providing N-pole, and a lower end providing S-pole, while the other permanent magnet 2a forming the pair has an upper end providing S-pole and a lower end providing N-pole. Each permanent magnet 2a produces a magnetic force (attractive force) with the levitating magnetic member 3. A magnetic flux



produced by the electromagnets 2b passes through a magnetic circuit including the yoke 2b1, levitating magnetic member 3, and a pair of gaps formed between the two end faces of the yoke 2b1 and magnetic member 3, to generate a magnetic force between the electromagnets 2b and magnetic member 3.

The magnetic force of the permanent magnets 2a and that of the electromagnets 2b have a mutually boosting effect where the permanent magnets 2a and electromagnets 2b produce magnetic fluxes in the same direction (i.e. have the same polarity), but attenuate each other where the magnetic fluxes are produced in opposite directions. Thus, the attractive force acting between the magnetic force generating devices 2 and levitating magnetic members 3 may be varied with respect to the magnetic force of the permanent magnets 2a by reversing polarity of an exciting current supplied to the electromagnets 2b (coils 2b2) or varying intensity thereof.

Each vehicle A includes a control device for controlling the exciting currents supplied to the electromagnets 2b to control the magnetic force of magnetic force generating devices 2, thereby to control levitation of the vehicle A above the guide rail B. The control by the control device of the exciting currents supplied to the electromagnets 2b will be described later.

The guide rail B includes primary coils 5 mounted in the bottom thereof, while each vehicle A includes a secondary conductor 6 supported by the lower frame 1 through a prop 6b. The primary coils 5 and secondary conductor 6 constitute a linear motor for driving the vehicle A. The secondary conductor 6 has a magnetic plate 6a applied thereto. The primary coils 5 produce magnetic fields to act on the secondary conductor 6 and propel the vehicle A.

The primary coils 5 are arranged at predetermined intervals along the guide rail B to save installation cost, and the vehicle A runs by inertia from one primary coil 5 to another. However, the primary coils 5 are, of necessity, arranged at and adjacent each station ST to decelerate the vehicle A to a standstill and to start and accelerate the vehicle A.

The guide rail B includes stopping electromagnets 7 arranged in positions opposed to each station ST to maintain the vehicle A at a standstill as magnetically levitated. The vehicle A includes stopping magnetic members 8 attached to the lower frame 1 to be attracted by the electromagnets 7. The magnetic members 8 are arranged in the front and rear and right and left corners of the vehicle A. Four electromagnets 7 are arranged in place opposite the station ST to act on the respective magnetic members 8.

Thus, the vehicle A is driven, under ground control, by the ground, primary type linear motor formed of the primary coils 5 and secondary conductor 6, and is stopped at each station ST and maintained still also under ground control. The controls of the primary coils 5 include deceleration, stoppage, starting and acceleration at and adjacent each station ST, and intermediate acceleration and deceleration between the stations ST. A ground controller effect these controls by varying direction and frequency of magnetic fields produced from the primary coils 5.

The vehicle A has a control device 9 mounted thereon. As shown in Fig. 12, the control device 9 has main functions to control, through a drive circuit 30, the exciting current supplied to the electromagnets 2b, and to exchange information with each station ST through communication units 11 and 12 by means of optical communication. The information exchanged includes information regarding the identification number and load conditions of the vehicle A, information regarding charging and discharging of a battery, and information regarding running and stoppage of the vehicle A.

Though not shown in Fig. 12, a total of four drive circuits 30 are provided to drive the four magnetic force generating devices 2 (electromagnets 2b) arranged in the front and rear and right and left corners of the vehicle A, respectively. The control device 9 transmits information regarding polarity and amount of the exciting current to each of the four drive circuits 30. Output of each drive circuit 30 (i.e. the exciting current) is fed back to the control device 9 through a current detector (or current detecting circuit) 13. The control device 9 also receives detection information from four gap sensors 4 each disposed centrally of the magnetic force generating device 2 (see Fig. 10).

Based on the detection information received from the gap sensors 4, the control device 9 controls the exciting currents supplied to the electromagnets 2b to secure a proper gap between the vehicle A and guide rail B. The control device 9 also varies the proper gap according to the weight of a load, and controls the exciting currents to zero steady level based on detection information received from the current detectors 13. That is, the control device 9 controls the exciting currents supplied to the electromagnets 2b within a small range centering on zero. Consequently, the magnetic forces of the electromagnets 2b are used to increase and decrease the magnetic forces of the magnetic force generating devices 2 with respect to the magnetic forces of the permanent magnets 2a. In this way, the attractive forces acting between the magnetic force generating devices 2 and levitating magnetic members 3 balance the gravity of the vehicle A including the load.

With the above control, the heavier the load is, the smaller is the gap between the vehicle A and guide rail B. Naturally, there is a physical limitation to the range of adjustment of the gap between the vehicle A and guide rail B. This magnetic levitation transport system includes an adjusting device for adjusting relative positions between the permanent magnets 2a and electromagnets 2b in the directions toward and away from the levitating magnetic members 3. With the position of the electromagnets 2b regarded as a reference position, the heavier the load is, the closer the permanent magnets 2a are moved to the levitating magnetic members 3. This increases the attractive force acting between the permanent magnets 2a and levitating magnetic members 3. A specific construction of this adjusting device C will be described with reference to Fig. 8.

As shown in Fig. 8, a load supporting deck 15 for supporting a load W is attached to the lower frame 1 through a spring 16. The load supporting deck 15 is movable downward, compressing the spring 16, under the weight of the load W. That is, the weights of the load W and load supporting deck 15 balance a restoring force of the spring 16. The frames 2a1 of the permanent magnets 2a are attached to a lower end of the load supporting deck 15 through parallel links 17. With vertical movement of the load supporting deck 15, the permanent magnets 2a are vertically movable by leverage.

As shown in Fig. 11, a lower end region of the load supporting deck 15 has an inserted T-shaped configuration including a vertical rod portion 15a vertically movably supported by the lower frame 1, and horizontal rod portions 15b extending right and left from a lower end of the vertical rod portion 15a. The parallel links 17 extending in the fore and aft direction are pivotally connected to opposite distal ends 15c of the horizontal rod portions 15b, respectively. The frames 2a1 of the permanent magnets 2a are pivotally connected to distal ends Q of the parallel links 17. The parallel links 17 are pivotally supported in intermediate positions thereof by support elements 28.

When the load supporting deck 15 moves vertically downward, lowering the opposite ends 15c of the horizontal rod portions 15b, each parallel link 17 acts as a lever having a pivotal connection R to the support element 28 acting as a fulcrum, the end 15c acting as a force applying point, and the distal end Q acting as an output point, to raise the permanent magnets 2a pivotally connected to the distal end Q.

The above construction provides the adjusting device C. The heavier the load is, the closer the permanent magnets 2a are moved to the levitating magnetic members 3. The spring 16 may have an

appropriately selected coefficient to realize a proper relationship between load weight and amount of movement.

This embodiment may be modified as follows:

(1) The specific construction of each magnetic force generating device 2 including the permanent magnets 2a and electromagnets 2b may be varied in many ways as set out hereunder. What is important is that the permanent magnets 2a and (the yoke 2b1 of) electromagnets 2b are arranged opposite the levitating magnetic members 3. It is of course possible to work the invention without moving the electromagnets 2b toward and away from the levitating magnetic members 3.

Fig. 13 (a) shows a magnetic force generating device 2 including a coil 2b2 of an electromagnet 2b mounted centrally of a yoke 2b1, and a pair of cylindrical permanent magnets fixedly mounted on the yoke 2b1. This magnetic force generating device 2 has a diminished overall construction.

Fig. 13 (b) shows a magnetic force generating device 2 including coils 2b2 of electromagnets 2b mounted on a yoke 2b1 as in the foregoing embodiment. The yoke 2b1 has opposite ends thereof cut thin, and a pair of cylindrical permanent magnets are fixedly mounted on the thin opposite ends of the yoke 2b1. With this construction, in a section of the magnetic circuit of the electromagnets 2b, part of the magnetic flux passes through the yoke 2b1, and part of the flux passes through the permanent magnets 2a. In this case, the electromagnets 2b have a lower efficiency than in the foregoing embodiment and in the modification shown in Fig. 13 (a), but have a higher efficiency than where intermediate portions or opposite ends of the yoke 1b1 are totally replaced with permanent magnets 2a.

This applies also to the modifications shown in Figs. 13 (c) and (d). In Fig. 13 (c), a yoke 2b1 has opposite ends defining cylindrical recesses centrally thereof in which cylindrical permanent magnets 2a are securely fitted, respectively. In Fig. 13 (d), a yoke 2b1 has opposite ends defining semicylindrical cutouts in which semicylindrical permanent magnets 2a are securely fitted, respectively. In each of the modifications shown in Figs. 13 (b) through (d), the permanent magnets 2a are rigidly attached to the yoke 2b1 without presenting projections. This facilitates positioning of the coils 2b2, and allows the magnetic force generating device 2 to have a compact construction compared with the foregoing embodiment.

(2) In the described magnetic levitation transport system, the gap between the vehicle and guide

rail is varied to bring the exciting currents for the electromagnets to zero steady level. However, the present invention is applicable to a transport system which does not employ such a system but simply controls the exciting currents for the electromagnets, based on the detection information from the gap sensors 4, so that the gap between the vehicle and guide rail become a predetermined value.

In this case, the heavier the load is, to the greater degree the exciting currents for the electromagnets are increased to increase the attractive force acting between the magnetic force generating devices and levitating magnetic members. The attractive force acting between the magnetic force generating devices and levitating magnetic members may be varied by moving the permanent magnets toward or away from the magnetic members, so that variations in the exciting currents for the electromagnets compensate for variations in the attractive force. That is, the variations in the exciting currents for the electromagnets may be limited to a small range.

(3) The construction for moving the permanent magnets the closer to the levitating magnetic members with the heavier load is not limited to the construction in the foregoing embodiment but may be varied in many ways. The vehicle may include a sensor for detecting the weight of a load, and actuators for moving the permanent magnets. Then, the control device may be adapted to operate the actuators in response to detection information received from the sensor.

(4) In converse to the foregoing embodiment, the electromagnets may be adapted vertically movable with the permanent magnets fixed to the vehicle. What is important is that the permanent magnets and electromagnets are movable relative to each other toward and away from the levitating magnetic members.

(5) It is not absolutely necessary to vary relative positions between the permanent magnets and electromagnets automatically in response to detection of a load weight. In the foregoing embodiment, for example, the control device 9 may refer to the load information transmitted from station ST to vehicle A through the communication units 11 and 12 to determine an amount of operation of actuators and operate the actuators to move the permanent magnets.

Alternatively, manually operable devices may be provided to adjust relative positions between the permanent magnets and electromagnets, to effect manual adjustment at a time of installation or maintenance.

A further embodiment will be described hereinafter.

An unmanned transport system in this embodiment is operable automatically to transport loads such as semiconductor wafers in a cleanroom. As shown in Fig. 9, the transport system includes a guide rail B extending along a running track of vehicles A. Each vehicle A is magnetically levitated and driven by a linear motor to run along the guide rail B as described hereinafter. A plurality of stations ST are arranged along the guide rail B, where the vehicles A may stop for loading and unloading operations.

As shown in Figs. 14 and 15, the guide rail B has levitating magnetic members 3 attached to lower surfaces of upper horizontal flanges thereof to be attracted by electromagnets acting as magnetic force generating devices 2 of each vehicle A. The electromagnets 2 are mounted on a lower frame 1 of the vehicle A and distributed to four, front and rear and right and left, corners of the vehicle A. Each electromagnet 2 includes a U-shaped core 2b1 having a pair of end faces opposed to one of the levitating magnetic members 3, and two coils 2b2 connected in series and wound around two bobbins mounted on the core 2b1.

A magnetic flux produced by the electromagnet 2 passes through a magnetic circuit including the core 2b1, levitating magnetic member 3, and a pair of gaps formed between the two end faces of the core 2b1 and magnetic member 3, to generate a magnetic force (attractive force) between the electromagnet 2 and magnetic member 3. As shown in Fig. 14, the levitating magnetic members 3 are magnetized in directions substantially at right angles to a running direction of the vehicle A (i.e. magnetized in right and left directions). Consequently, depending on directions of the magnetic fluxes produced by the electromagnets 2, the magnetic forces acting between the electromagnets 2 and levitating magnetic members 3 become repulsive forces. That is, when magnetic fluxes are produced in directions indicated by broken line arrows in Fig. 14, attractive forces are generated between the electromagnets 2 and levitating magnetic members 3. When magnetic fluxes are produced in directions opposite to the broken line arrows, repulsive forces are generated between the electromagnets 2 and levitating magnetic members 3.

Each electromagnet 2 includes a gap sensor 4 disposed centrally thereof to detect a gap between the vehicle A and guide rail B. The vehicle A includes a control device operable, in response to detection information received from the gap sensors 4, to control exciting currents supplied to the electromagnets 2 to control the magnetic forces of the electromagnets 2, thereby to control levitation of the vehicle A above the guide rail B. The control by the control device will be described later.

The guide rail B includes primary coils 5 mounted in the bottom thereof. Each vehicle A includes a secondary conductor 6 supported by the lower frame 1 through a prop 6b. The primary coils 5 and secondary conductor 6 constitute a linear motor for driving the vehicle A. The secondary conductor 6 has a magnetic plate 6a applied thereto. The primary coils 5 produce magnetic fields to act on the secondary conductor 6 and propel the vehicle A.

The primary coils 5 are arranged at predetermined intervals along the guide rail B to save installation cost, and the vehicle A runs by inertia from one primary coil 5 to another. However, the primary coils 5 are, of necessity, arranged at and adjacent each station ST to decelerate the vehicle A to a standstill and to start and accelerate the vehicle A.

The guide rail B includes stopping electromagnets 7 arranged in positions opposed to each station ST to maintain the vehicle A at a standstill as magnetically levitated. The vehicle A includes stopping magnetic members 8 attached to the lower frame 1 to be attracted by the electromagnets 7. The magnetic members 8 are arranged in the front and rear and right and left corners of the vehicle A. Four electromagnets 7 are arranged in place opposite the station ST to act on the respective magnetic members 8.

Thus, the vehicle A is driven, under ground control, by the ground, primary type linear motor formed of the primary coils 5 and secondary conductor 6, and is stopped at each station ST and maintained still also under ground control. The controls of the primary coils 5 include deceleration, stoppage, starting and acceleration at and adjacent each station ST, and intermediate acceleration and deceleration between the stations ST. A ground controller effect these controls by varying direction and frequency of magnetic fields produced from the primary coils 5.

The vehicle A has a control device 9 mounted thereon. As shown in Fig. 16, the control device 9 has main functions to control, through a drive circuit 30, the exciting current supplied to the electromagnets 2, and to exchange information with each station ST through communication units 11 and 12 by means of optical communication. The information exchanged includes information regarding the identification number and load conditions of the vehicle A, information regarding charging and discharging of a battery, and information regarding running and stoppage of the vehicle A.

Though not shown in Fig. 16, a total of four drive circuits 30 are provided to drive the four electromagnets 2 arranged in the front and rear and right and left corners of the vehicle A, respectively. The control device 9 transmits information

regarding polarity and amount of the exciting current to each of the four drive circuits 30. The control device 9 also receives detection information from four gap sensors 4 mentioned hereinbefore.

Based on the detection information received from the gap sensors 4, the control device 9 effects a feedback control to vary the exciting currents supplied to the electromagnets 2, to secure a proper gap between the vehicle A and guide rail B. That is, the control device 9 causes the attractive forces acting between the electromagnets 2 and levitating magnetic members 3 to balance the weight of the vehicle A including a load supported thereon. Thus, the heavier the load is, the greater becomes the exciting currents supplied to the electromagnets 2.

The weight of the vehicle A changes suddenly when transferring a load from a station ST to the vehicle A or vice versa. As a result, the vehicle A undergoes transient vertical vibrations until reinstatement in a normal, steady state in which the attractive force and weight are balanced. Further, the vehicle A may encounter vertical vibrations due to some disturbance during a run, particularly when carrying no load.

In the magnetic levitation transport system of this embodiment, the control device 9 effects a control in order to damp such vibrations quickly and to prevent the vehicle A from moving too close to the guide rail B and causing the electromagnets 2 to contact the levitating magnetic members 3. This control will be described with reference to the block diagram in Fig. 17.

The control device 9 includes a comparator circuit 9a for comparing a detection value from each gap sensor 4 with a predetermined lower limit value. If the detection value is less than the lower limit value, that is if the vehicle A is too close to the guide rail B, the control device 9 operates a switch circuit 9b to apply a predetermined repulsive current level to a drive circuit 30 and excite the electromagnet 2 with an exciting current of opposite polarity to normal. As a result, a magnetic flux is produced in the opposite direction to a broken line arrow in Fig. 14, to generate a repulsive force between the electromagnet 2 and levitating magnetic member 3. This repulsion generating current (i.e. the exciting current of opposite polarity) is a pulsed current lasting only a short time, and the control device 9 presently returns to the normal feedback control.

In the normal feedback control where the detection values are above the lower limit value, the control device 9 adjusts exciting currents of positive polarity based on the detection values from the gap sensors 4. Specifically, an operational amplifier circuit 9c outputs a deviation of the detection value of each gap sensor 4 from a predetermined target

value, to the drive circuit 30 through the switch circuit 9b. The electromagnet 2 is excited by a current of positive polarity corresponding to the deviation. As a result, a magnetic flux is produced in the direction indicated by the broken line arrow in Fig. 14, to generate an attractive force between the electromagnet 2 and levitating magnetic member 3 which balances the weight of the vehicle A.

This embodiment may be modified as follows:

- (1) In the described embodiment, a repulsion generating current level applied to the drive circuit 30 may be varied with reference to the weight of a load when the detection values of the gap sensors 4 are below the lower limit value, i.e. when the vehicle A has moved too close to the guide rail B. That is, vertical vibrations of the vehicle A are damped with increased speed by varying the repulsive forces generated between the electromagnets 2 and levitating magnetic members 3 according to an inertial force of the load. The weight of the load may be included in the load information communicated from station ST to vehicle A, for example.
- (2) The mode of switching electrification of the electromagnets to switch the magnetic forces generated between the electromagnets and levitating magnetic members, between attractive forces and repulsive forces, is not limited to the polarity inversion of the exciting currents supplied to the electromagnets as in the foregoing embodiment. For example, each electromagnet may include a pair of coils wound in opposite directions for selective excitation.
- (3) In the foregoing embodiment, the levitating magnetic members 3 are magnetized in right and left directions normal to the running direction of the vehicle A. Instead, the magnetic members may be magnetized vertically so that upper/lower surfaces present N/S-poles. In this case, each electromagnet employs an I-shaped core having one of the two end faces opposed to the levitating magnetic member.
- (4) In the foregoing embodiment, the exciting current for the electromagnets 2 are varied based on the detection information from the gap sensors 4, to maintain a proper gap between the vehicle A and guide rail B. The present invention is applicable to what is called a zero power levitation control in which the exciting currents for the electromagnets 2 are fed back, and the proper gap is varied to bring the exciting currents to zero steady level. That is, the core 2b1 of each electromagnet 2 is formed of a material attracted by a levitating magnetic member 3 in the form of a permanent magnet, and this attractive force is used as a steady levitating magnetic force. It is also possible to use permanent

magnets with the electromagnets 2 to obtain increased steady levitating magnetic forces in times of zero exciting current.

A further embodiment will be described hereinafter.

Figs. 19 and 20 show a construction for levitating a vehicle A above a guide rail B in this embodiment. The guide rail B has levitating magnetic members 3 attached to lower surfaces of upper horizontal flanges thereof to be attracted by magnetic force generating devices 2 of the vehicle A. The magnetic force generating devices 2 are mounted on a lower frame 1 of the vehicle A and distributed to four, front and rear and right and left, corners of the vehicle A. Each magnetic force generating device 2 includes a pair of electromagnets 2b and a permanent magnet 2a mounted on a yoke between the electromagnets 2b. The electromagnets 2b are in the form of coils connected in series and supplied with a predetermined exciting current.

A magnetic flux produced by the electromagnets 2b and permanent magnet 2a passes through a magnetic circuit including the permanent magnet 2a, yoke of the electromagnets 2b, levitating magnetic member 3, and a pair of gaps formed between two end faces of the yoke and magnetic member 3, to generate a magnetic force (attractive force) between the magnetic force generating device 2 and magnetic member 3. The magnetic force of the permanent magnet 2a and that of the electromagnets 2b have a mutually boosting effect where the permanent magnet 2a and electromagnets 2b produce magnetic fluxes in the same direction, but attenuate each other where the magnetic fluxes are produced in opposite directions.

Thus, the attractive force acting between the magnetic force generating device 2 and levitating magnetic member 3 may be varied with respect to the magnetic force of the permanent magnet 2a by varying the exciting current supplied to the coils of electromagnets 2b between opposite polarities across zero. That is, the permanent magnets 2a are utilized to levitate the vehicle A while saving power consumed by the electromagnets 2b. This levitation control will be described later.

A construction for propelling the vehicle A forward and backward along the guide rail B will be described next.

The guide rail B includes primary coils 5 mounted in the bottom thereof, while each vehicle A includes a secondary conductor 6 supported by the lower frame 1 through a prop 6b. The primary coils 5 and secondary conductor 6 constitute a linear motor for driving the vehicle A. The secondary conductor 6 has a magnetic plate 6a applied thereto. The primary coils 5 produce magnetic fields to act on the secondary conductor 6 and

propel the vehicle A.

The primary coils 5 are arranged at predetermined intervals along the guide rail B to save installation cost. The vehicle A receives a forward or backward thrust from a primary coil 5 when passing over it, and runs by inertia to a next primary coil 5. However, the primary coils 5 are, of necessity, arranged at and adjacent each station ST to decelerate the vehicle A to a standstill and to start and accelerate the vehicle A.

The guide rail B includes stopping electromagnets 7 arranged in positions opposed to each station ST to maintain the vehicle A at a standstill as magnetically levitated. The vehicle A includes stopping magnetic members 8 attached to the lower frame 1 to be attracted by the electromagnets 7. The magnetic members 8 are arranged in the front and rear and right and left corners of the vehicle A. Four electromagnets 7 are arranged in place opposite the station ST to act on the respective magnetic members 8.

Controls of the magnetic force generating devices 2 of the vehicle A and the primary coils 5 acting as propelling force generating means will be described with reference to Fig. 18.

As shown in Fig. 18, a levitation control device 9 mounted on the vehicle A controls, through a drive circuit 30, the exciting current supplied to the electromagnet 2b, thereby to control the levitating force of the magnetic force generating device 2.

The exciting current for the electromagnet 2b is fed back to the levitation control device 9 through a current detecting circuit 13. As shown in Fig. 19, the vehicle A includes gap sensors 4 each disposed centrally of the magnetic force generating device 2 for detecting a gap between the vehicle A and guide rail B. These gap sensors 4 transmit detection signals to the levitation control device 9. Though not shown in Fig. 18, the drive circuit 30 and current detecting circuit 31 are provided for each magnetic force generating device 2.

The levitation control device 9 controls the exciting currents for the electromagnets 2b, i.e. the levitating forces of the magnetic force generating devices 2, based on detection information from the current detecting circuits 13 and gap sensors 4 constituting a levitated state detecting device for detecting a difference between an actual levitated state and a predetermined proper levitated state. Specifically, the levitation control device 9 effects what is called a zero power levitation control to bring the exciting currents for the electromagnets 2b to zero (predetermined proper level) in a steady state where the gap sensors 4 detect no variation in the gap.

In the steady state, the vehicle A is levitated above the guide rail B with a gap therebetween determined only by the magnetic forces of the

permanent magnets 2a. The exciting currents for the electromagnets 2b are varied within a very small range between opposite polarities across zero when variations occur with the above gap.

In the zero power levitation control, the gap in the steady state is variable with variations in the weight of the vehicle A including a load W. When the weight increases, for example, the vehicle A first sinks to increase the gaps detected by the gap sensors 4. Then, the levitation control device 9 acts to increase the exciting currents for the electromagnets 2b in a direction to compensate for the increase in the gaps. Even after an original gap is restored, the exciting currents are allowed to flow to cope with the increase in the weight. Consequently, the electromagnets 2b are excited in a direction to diminish the gap, to establish a steady state in which the exciting currents become zero for a smaller gap than the original gap. That is, an increase in the weight result in a diminished gap in the steady state.

Thus, the detection values of the gap sensors 4 in the steady state in which the zero power levitation is established correspond to state values variable with variations in the weight of the vehicle A, and the gap sensors 4 correspond to state value detecting means. The magnetic levitation transport system in this embodiment uses these state values in controlling the forward or backward propelling force applied to the vehicle A, to realize substantially constant acceleration and deceleration regardless of the weight of the load W.

Under the condition of a fixed forward or backward propelling force, acceleration (or deceleration) is variable with variations in the weight of the vehicle A including the load W according to Newton's second law. This is undesirable since variable acceleration (or deceleration) time occurs before attaining a desired speed. Difficulties are encountered particularly in controlling deceleration and stoppage of the vehicle A. To eliminate this inconvenience, the forward or backward propelling force is varied in proportion to the state values corresponding to the weight of the vehicle A, to obtain constant acceleration (or deceleration) regardless of weight variations. This aspect will be described with reference to Fig. 18.

As shown in Fig. 18, the state values detected by the gap sensors 4 acting as the state value detecting means, or more precisely state values the levitation control device 9 derives from the detection values of the gap sensors 4 in the steady state, are transmitted to a propelling force control device 59 through communication units 11 and 12.

The communication units 11 and 12 are infrared type bidirectional communication units mounted on the vehicle A and the ground (such as each station ST), respectively. These communication units are

used in exchange of the identification number of the vehicle A, information regarding charging and discharging of a battery, and information regarding starting and stoppage of the vehicle A, as well as the above state values.

The propelling force control device 59 controls direction and magnitude of the propelling force the primary coils 5 acting as propelling force generating means apply to the vehicle A through the secondary conductor 6. The direction of the propelling force applied to vehicle A is switched by switching the direction of magnetic fields induced by the primary coils 5. Thus, a forward propelling force or backward propelling force are selectively applied to the passing vehicle A to accelerate or decelerate the vehicle A.

Since the primary coils 5 are arranged in spaced relations as noted hereinbefore, it is inefficient to accelerate or decelerate the vehicle A by varying frequency. Instead of varying frequency, an AC voltage applied to the primary coils 5 is subjected to phase control to vary effective voltage, thereby varying magnitude of the propelling force (torque).

Propelling force control devices 59 for controlling intermediate accelerating primary coils 5 arranged between stations ST vary the effective voltage in proportion to the state values (the weight of vehicle A and load W) transmitted from the vehicle A through the communication units 11 and 12. As a result, the magnitude of the propelling force the primary coils 5 apply to the vehicle A is adjusted to a proper value according to the weight of the load W.

Similarly, a propelling force control device 59 for controlling a decelerating primary coil 5 disposed upstream of each station ST, and a propelling force control device 59 for controlling an accelerating primary coil 5 disposed immediately downstream of each station ST, also vary the effective voltage to be applied to the primary coils 5 in proportion to the state values. In this way, substantially constant deceleration (or acceleration) is obtained regardless of variations in the weight of the load W.

A propelling force control device 59 for controlling a primary coil 5 opposed to each station ST effects the following control in order to cause the vehicle A to stop smoothly at a predetermined position. Though not shown in Fig. 19, the vehicle A includes a slit plate (referenced 56 in Fig. 18) elongated in the fore and aft direction and mounted laterally of the lower frame 1, while the guide rail B includes an optical sensor (photo interrupter) 57 having a light emitter and a light receiver defining a space therebetween through which the slit plate is movable. The slit plate defines slits for allowing passage of light of the optical sensor therethrough

and non-slit portions for shielding the light, which are arranged alternately at fixed intervals. The slit plate and optical sensor 57 constitute a linear encoder.

A position/speed detecting device 58 included in a control device of each station ST derives a current position and current speed of the vehicle A from a detection signal received from the optical sensor 57, and applies this information to the propelling force control device 59. Based on the current position and speed of the vehicle A, the propelling force control device 59 controls the effective voltage applied to the primary coil 5 to slow down the vehicle A gradually to be at creep speed a little before a stopping position. That is, the effective voltage applied to the primary coil 5 is gradually lowered based on a distance from the current position to the stopping position and a difference between the current speed and a predetermined proper speed. When a current position of the vehicle A decelerated to creep speed agrees with the stopping position, the stopping electromagnets 7 mentioned hereinbefore are excited to hold the vehicle A at the stopping position.

In the above stopping control also, the effective voltage applied to the primary coil 5 must be varied in proportion to the state values corresponding to the vehicle A including the load W. In practice, this is achieved by varying, by degrees and according to the state values, gain in feedback control of the effective voltage applied to the primary coil 5, based on a difference between the proper speed and current speed.

This embodiment may be modified as follows:

(1) The levitation control in the above embodiment is what is called zero power control to bring the exciting currents for the electromagnets to zero in the steady state. The present invention is not limited such control, but may allow certain exciting currents to flow to the electromagnets in the steady state. This is a control for maintaining energy supplied to the magnetic force generating devices at a predetermined proper value.

(2) The invention is applicable where a levitation control is effected to control the levitating force of the magnetic force generating devices to secure a predetermined proper gap between the vehicle and guide rail despite variations in the weight of the load (and vehicle A). This is a case where the levitation control device 9 controls the exciting currents supplied to the electromagnets 2b based on a difference between the predetermined proper gap and the gap detected by the gap sensors 4 acting as levitated state detecting means. In this case, the current detecting circuits 13 correspond to the state value detecting device for detecting the levitating force of the



magnetic force generating device, and detect state values (exciting current levels) corresponding to the weight of the load (and the vehicle).

(3) The state value detecting device for detecting state values variable with variations in the weight of the vehicle does not have to use the gap sensors 4 and current detecting circuits 13 constituting the levitated state detecting device. The state value detecting device may employ gap sensors and the like provided specially for this purpose.

(4) Instead of providing communication units 12 for all positions where the primary coils are installed as in the foregoing embodiment, the communication units 12 may be provided only for the stations ST. Then, the state values transmitted from the vehicle A to each station ST may be transferred to the propelling force control devices of the primary coils adjacent to this station ST.

(5) The magnetic force generating devices and control devices therefor, and the state value detecting devices, may be installed on the ground. The present invention is applicable to such a case.

(6) Instead of deriving a weight from the state values detected in the predetermined proper levitated state as in the foregoing embodiment, a weight may be derived from state values detected during a transitional control process to the predetermined proper levitated state. That is, a variation in the gap resulting from a unit amount increase in the levitating force increases or decreases according to a weight, and therefore the weight may be derived from such variation.

## Claims

1. A magnetic levitation transport system comprising:

a magnetic levitation vehicle;

lines extending through predetermined blocks of a running track of said vehicle to transmit a high frequency sine-wave current therethrough;

wherein said vehicle is driven by a linear motor, and includes levitating magnetic force generating means to attract levitating magnetic members extending along said running track, a pickup coil resonant with a frequency of said lines to generate an electromotive force, and a battery chargeable by said pickup coil, said levitating magnetic force generating means receiving power from said pickup coil and/or said battery.

2. A magnetic levitation transport system as defined in claim 1, wherein said lines are included in induction line units installed in said predetermined blocks and extending along inner walls of a guide rail.

3. A magnetic levitation transport system as defined in claim 2, wherein each of said induction line units includes, besides one of said lines, an elongate plate-like aluminum bracket extending along said guide rail, and pairs of upper and lower horizontal hangers supported by said bracket and arranged at predetermined intervals along said guide rail, and a pair of plastic ducts attached to distal ends of said hangers and extending along said guide rail.

4. A magnetic levitation transport system as defined in claim 3, wherein each of said lines is a strand wire formed of thin insulated wires and connected to one of said duct, and covered with an insulator.

5. A magnetic levitation transport system as defined in claim 1, wherein said levitating magnetic force generating means comprises electromagnets, said battery supplying power to said electromagnets in portions of said running track destitute of said lines.

6. A magnetic levitation transport system as defined in claim 1, wherein said levitating magnetic force generating means includes electromagnets and permanent magnets.

7. A magnetic levitation transport system as defined in claim 6, wherein said electromagnets and said permanent magnets are arranged opposite said levitating magnetic members, respectively.

8. A magnetic levitation transport system as defined in claim 7, wherein each of said permanent magnets is formed cylindrical to surround one of said electromagnets.

9. A magnetic levitation transport system comprising:

a magnetic levitation vehicle;

lines extending through predetermined blocks of a running track of said vehicle to transmit a high frequency sine-wave current therethrough;

wherein said vehicle is driven by a linear motor, and includes levitating magnetic force generating means to attract levitating magnetic members extending along said running track, control means for controlling a magnetic force



- of said levitating magnetic force generating means, a pickup coil resonant with a frequency of said lines to generate an electromotive force, and a battery chargeable by said pickup coil, said levitating magnetic force generating means including electromagnets and permanent magnets, and receiving power from said pickup coil and/or said battery.
10. A magnetic levitation transport system as defined in claim 9, wherein said electromagnets and said permanent magnets are arranged opposite said levitating magnetic members, respectively.
11. A magnetic levitation transport system as defined in claim 10, wherein each of said permanent magnets is formed cylindrical to surround one of said electromagnets.
12. A magnetic levitation transport system as defined in claim 11, wherein each of said electromagnets includes a coil mounted centrally of a yoke, and a pair of said cylindrical permanent magnets are fixedly mounted on said yoke.
13. A magnetic levitation transport system as defined in claim 11, wherein each of said electromagnets includes a coil mounted centrally of a yoke having thin opposite ends, and a pair of said cylindrical permanent magnets are fixedly mounted on said thin opposite ends.
14. A magnetic levitation transport system as defined in claim 11, wherein a pair of said electromagnets share a yoke having opposite ends defining cylindrical recesses centrally thereof in which said cylindrical permanent magnets are securely fitted, respectively.
15. A magnetic levitation transport system as defined in claim 11, wherein a pair of said electromagnets share a yoke having opposite ends defining semicylindrical cutouts in which semicylindrical permanent magnets are securely fitted, respectively.
16. A magnetic levitation transport system as defined in claim 9, further comprising adjusting means for adjusting relative positions between said permanent magnets and said electromagnets in directions toward and away from said levitating magnetic members.
17. A magnetic levitation transport system as defined in claim 16, wherein said adjusting means is automatically operable to move said permanent magnets relative to said electromagnets the closer to said levitating magnetic members with the heavier load placed on said vehicle.
18. A magnetic levitation transport system as defined in claim 16, wherein said vehicle further includes gap detecting means for detecting a gap between said vehicle and said guide rail, said control means being operable to control said magnetic force such that a value detected by said gap detecting means become a predetermined value.
19. A magnetic levitation transport system as defined in claim 16, wherein said vehicle further includes current detecting means for detecting the exciting currents supplied to said electromagnets, said control means being operable, in response to detection information received from said current detecting means, to control said magnetic force such that said exciting currents become zero steady level.
20. A magnetic levitation transport system as defined in claim 1, wherein said levitating magnetic force generating means includes a plurality of electromagnets, and said levitating magnetic members are magnetized substantially at right angles to a running direction of said vehicle, said vehicle further including control means for controlling magnetic forces of said electromagnets, said control means being operable to control electrification of said electromagnets such that magnetic forces acting between said electromagnets and said levitating magnetic members are switched between attractive forces and repulsive forces.
21. A magnetic levitation transport system as defined in claim 20, wherein each of said electromagnets includes a gap sensor mounted centrally thereof to detect a gap between said vehicle and said guide rail.
22. A magnetic levitation transport system as defined in claim 1, further comprising levitated state detecting means for detecting a difference between a predetermined proper levitated state and an actual levitated state provided by a levitating force of said levitating magnetic force generating means, levitation control means operable in response to detection information received from said levitated state detecting means to control the levitating force of said levitating magnetic force generating means, thereby to maintain said predetermined proper levitated state, propelling force generat-

ing means for applying a forward or backward propelling force to said vehicle along said guide rail, and propelling force control means for controlling said propelling force generating means.

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23. A magnetic levitation transport system as defined in claim 22, further comprising state value detecting means for detecting a state value variable with variations in weight of said vehicle, said propelling force control means being operable in response to detection information received from said state value detecting means to control said forward or backward propelling force.
24. A magnetic levitation transport system as defined in claim 22, wherein said levitated state detecting means is operable to detect a difference between a predetermined proper gap and an actual gap between said vehicle and said guide rail, said levitation control means is operable to control the levitating force of said levitating magnetic force generating means to bring said actual gap to said proper gap, and said state value detecting means is operable to detect the levitating force of said levitating magnetic force generating means.
25. A magnetic levitation transport system as defined in claim 22, wherein said levitated state detecting means is operable to detect a difference between a predetermined proper value and energy supplied to said levitating magnetic force generating means, and variations in a gap between said vehicle and said guide rail, said levitation control means is operable to control the levitating force of said levitating magnetic force generating means to bring said energy supplied to said magnetic force generating means to said predetermined proper value in the absence of variations in said gap, and said state value detecting means is operable to detect said gap.
26. A magnetic levitation transport system as defined in claim 22, wherein said levitated state detecting means includes current detecting circuits and gap sensors, the levitating force of said magnetic force generating means being controllable based on detection information from said gap sensors.

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FIG. 1

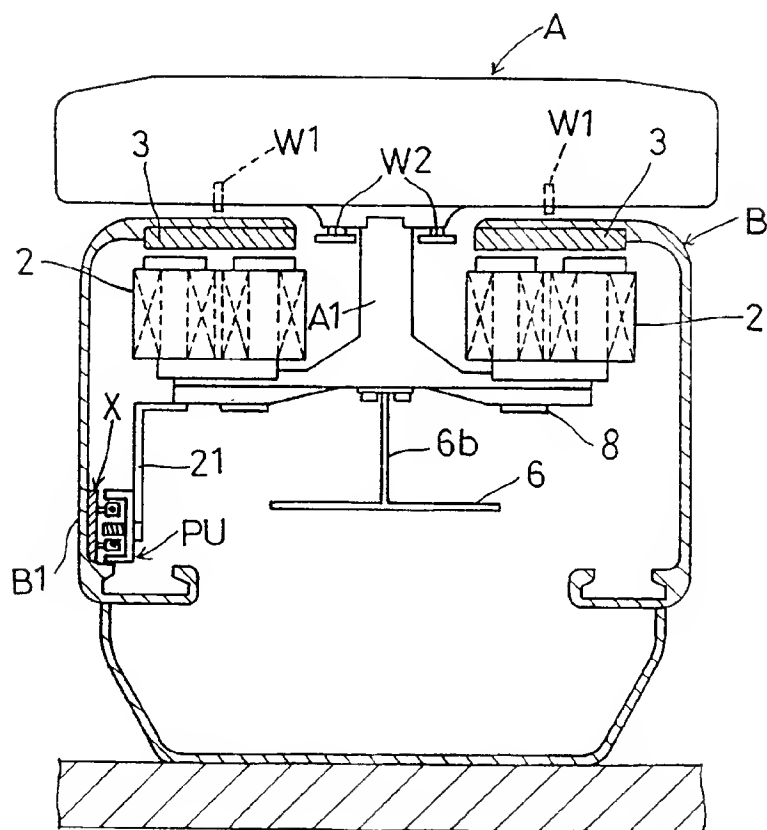


FIG. 2

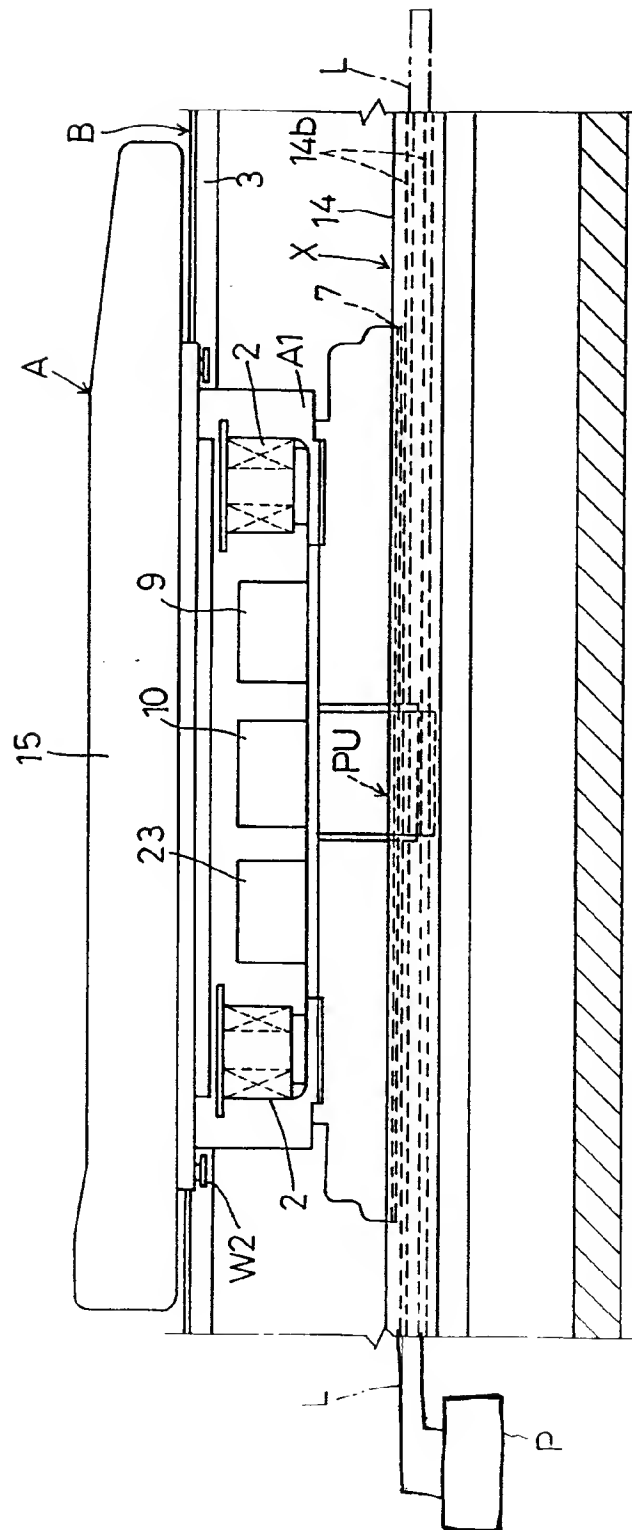


FIG. 3

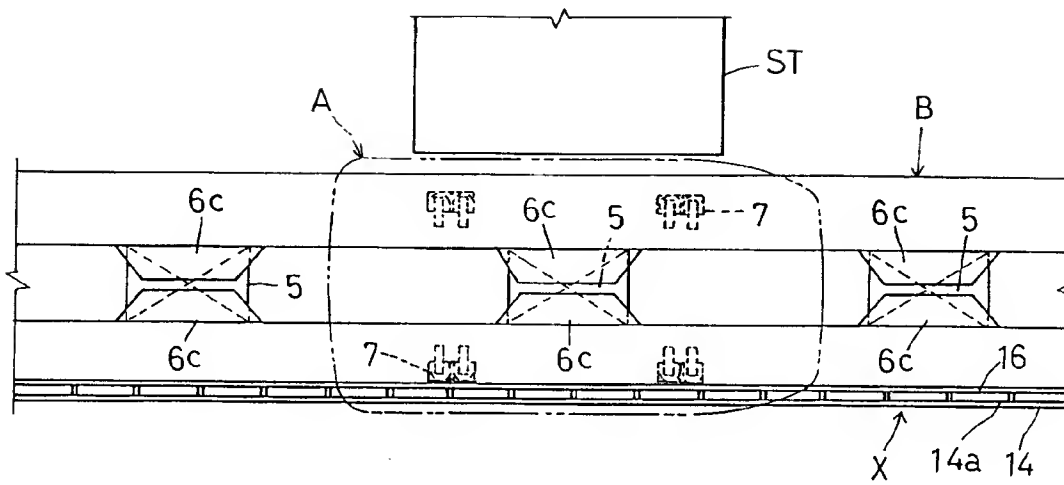


FIG. 4

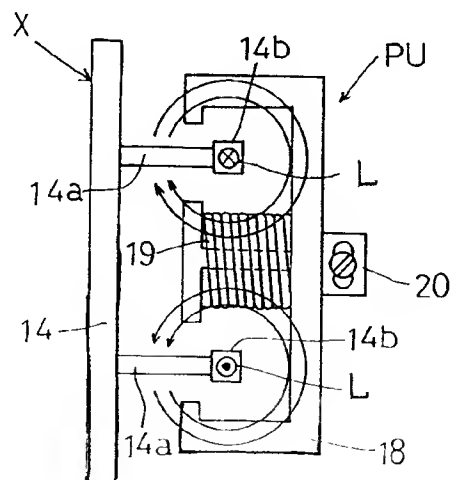


FIG. 5

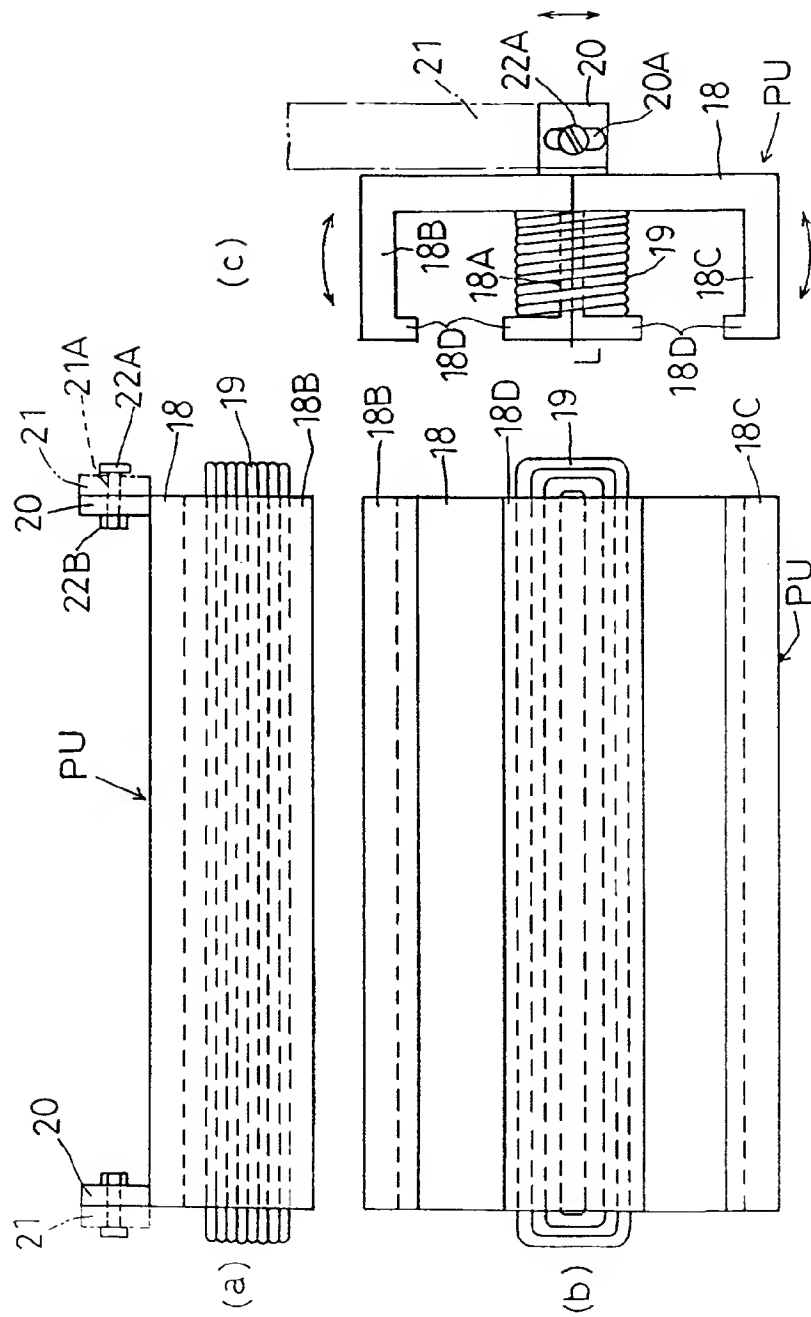


FIG. 6

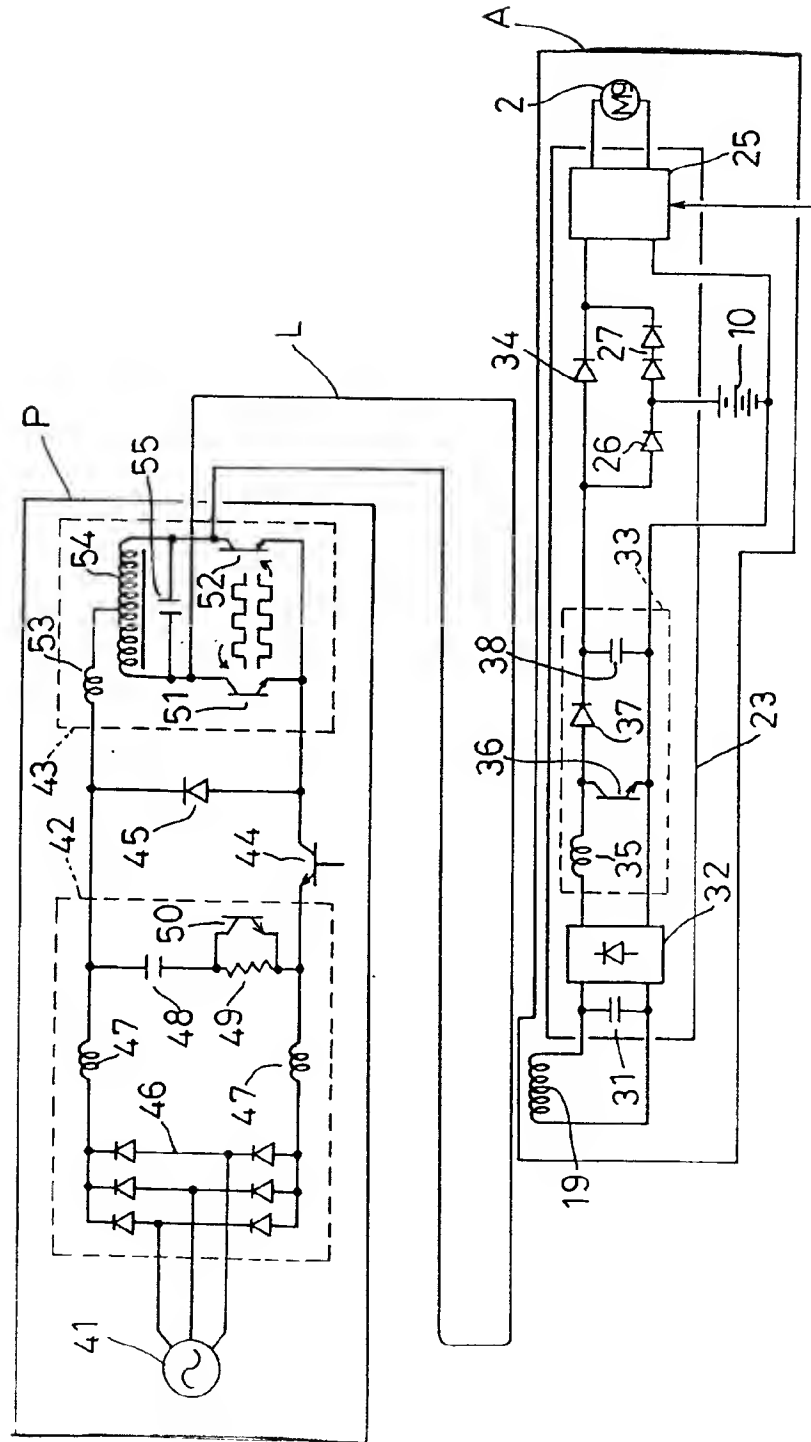


FIG. 7

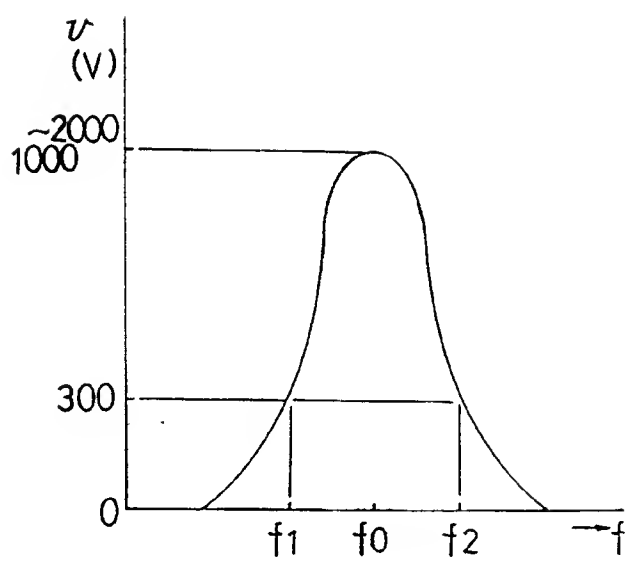




FIG 8

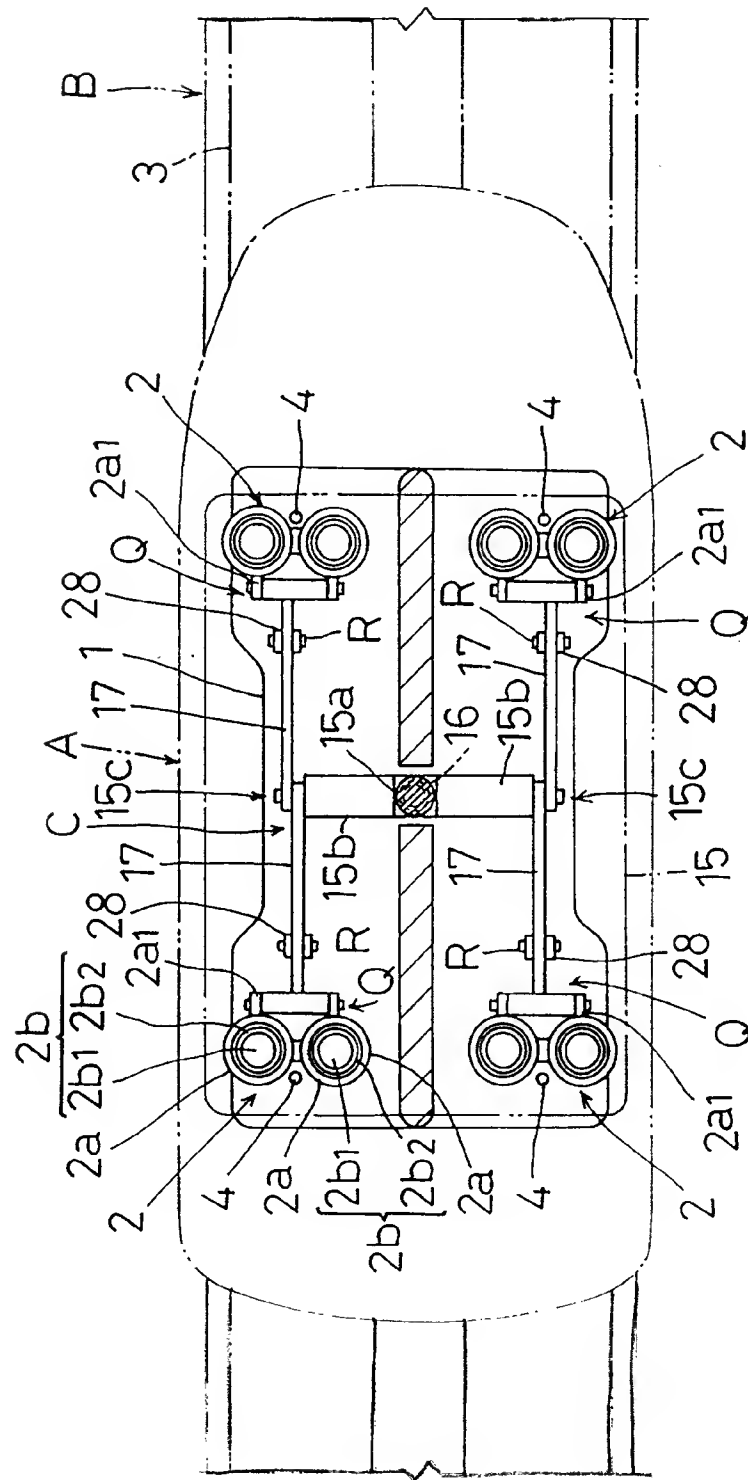


FIG 9

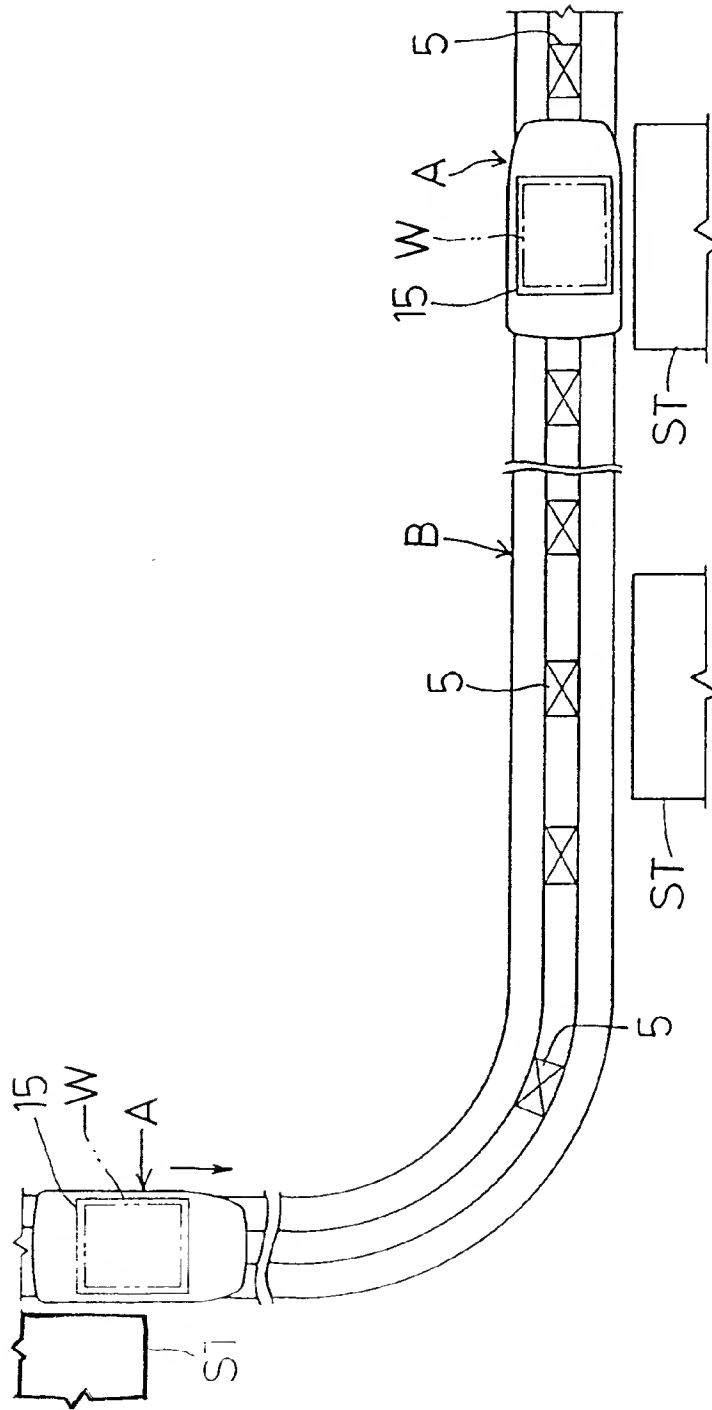


FIG 10

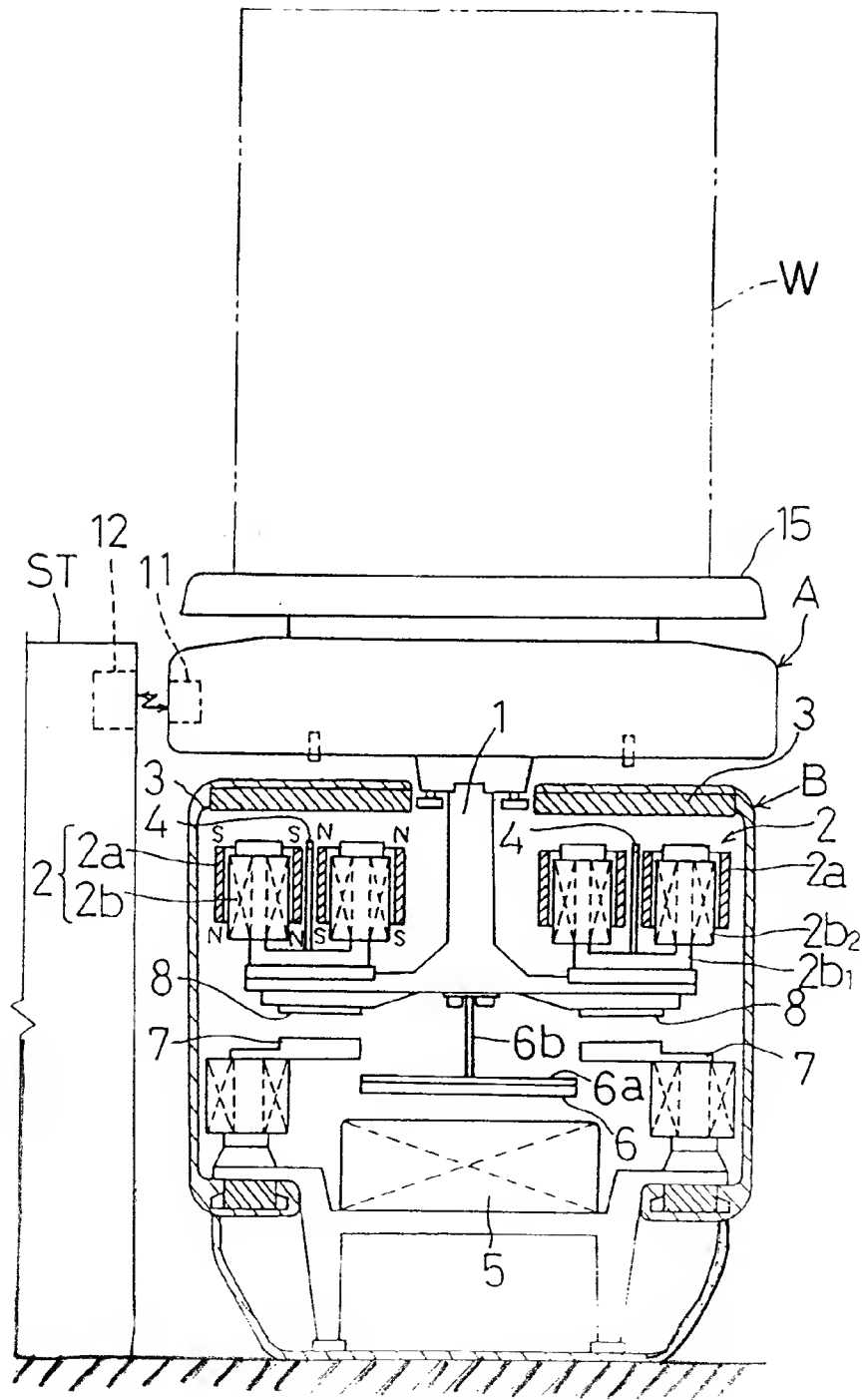


FIG 11

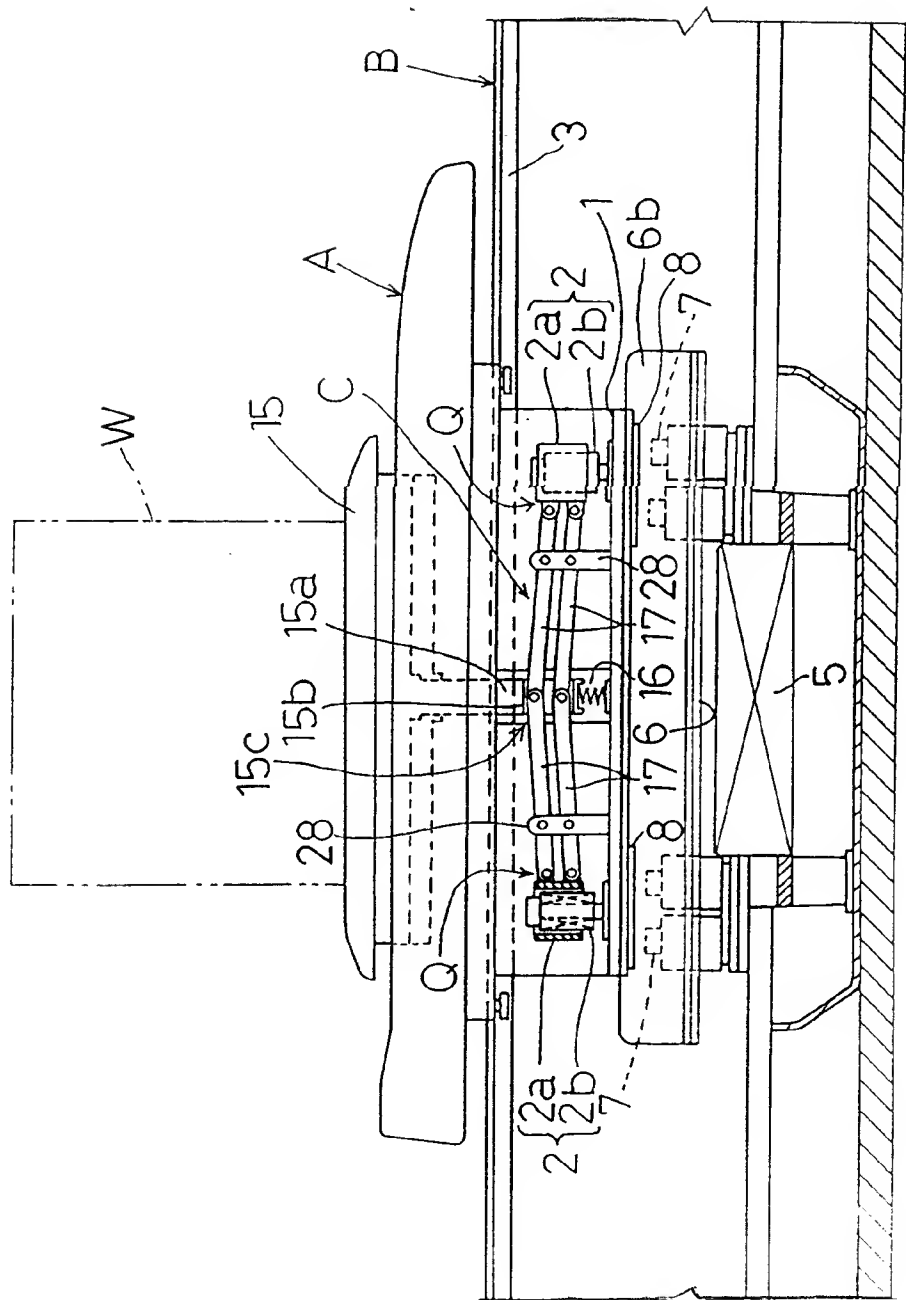


FIG 12

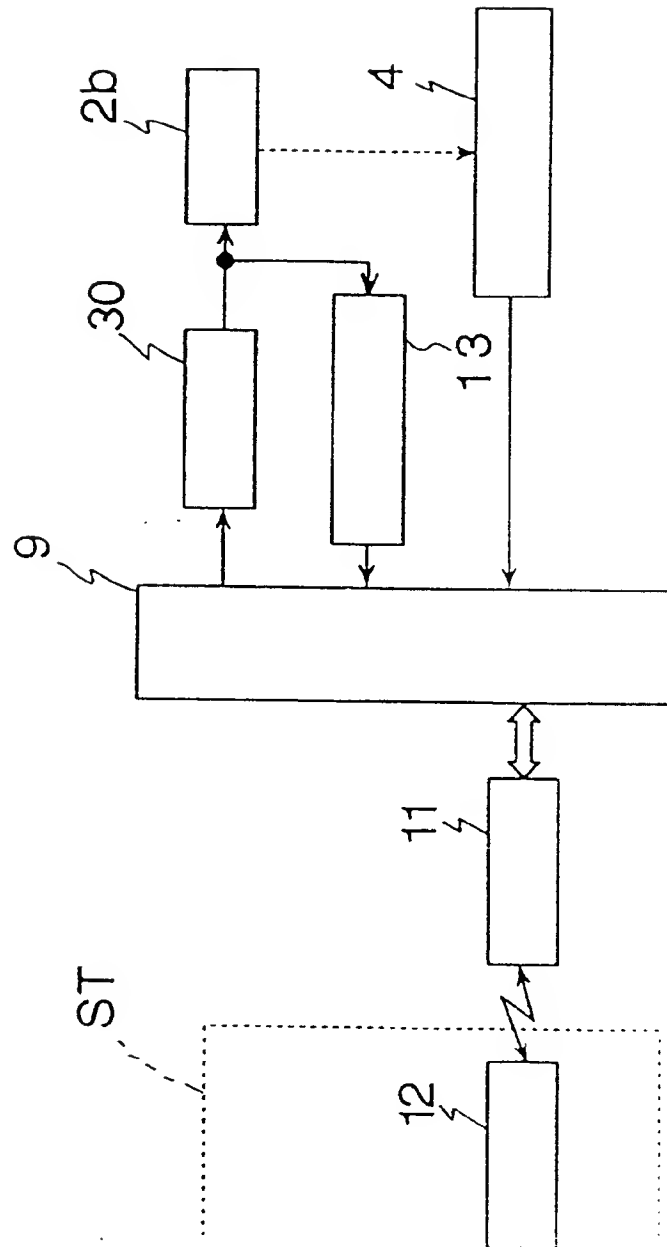


FIG 13

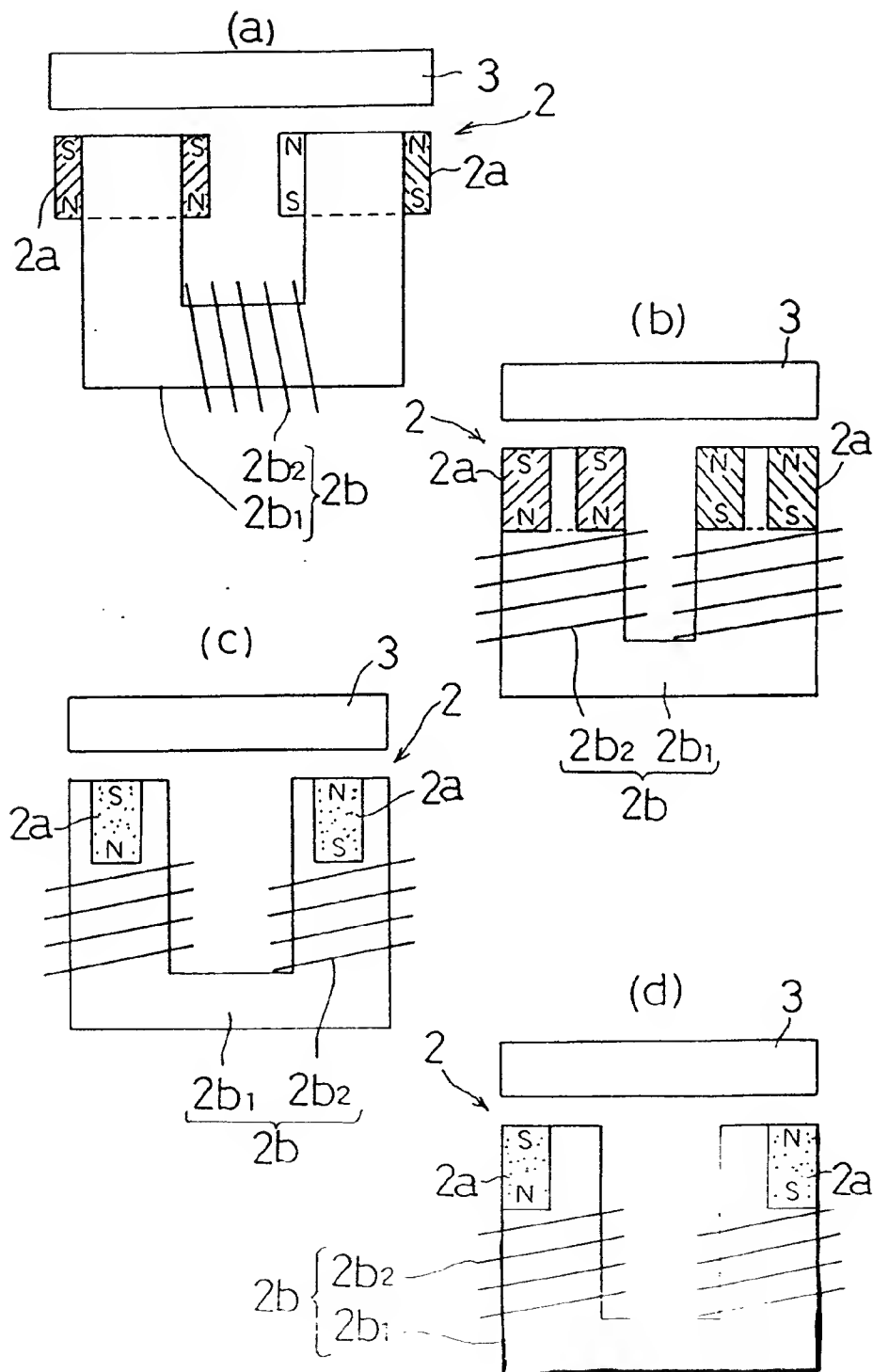


FIG 14

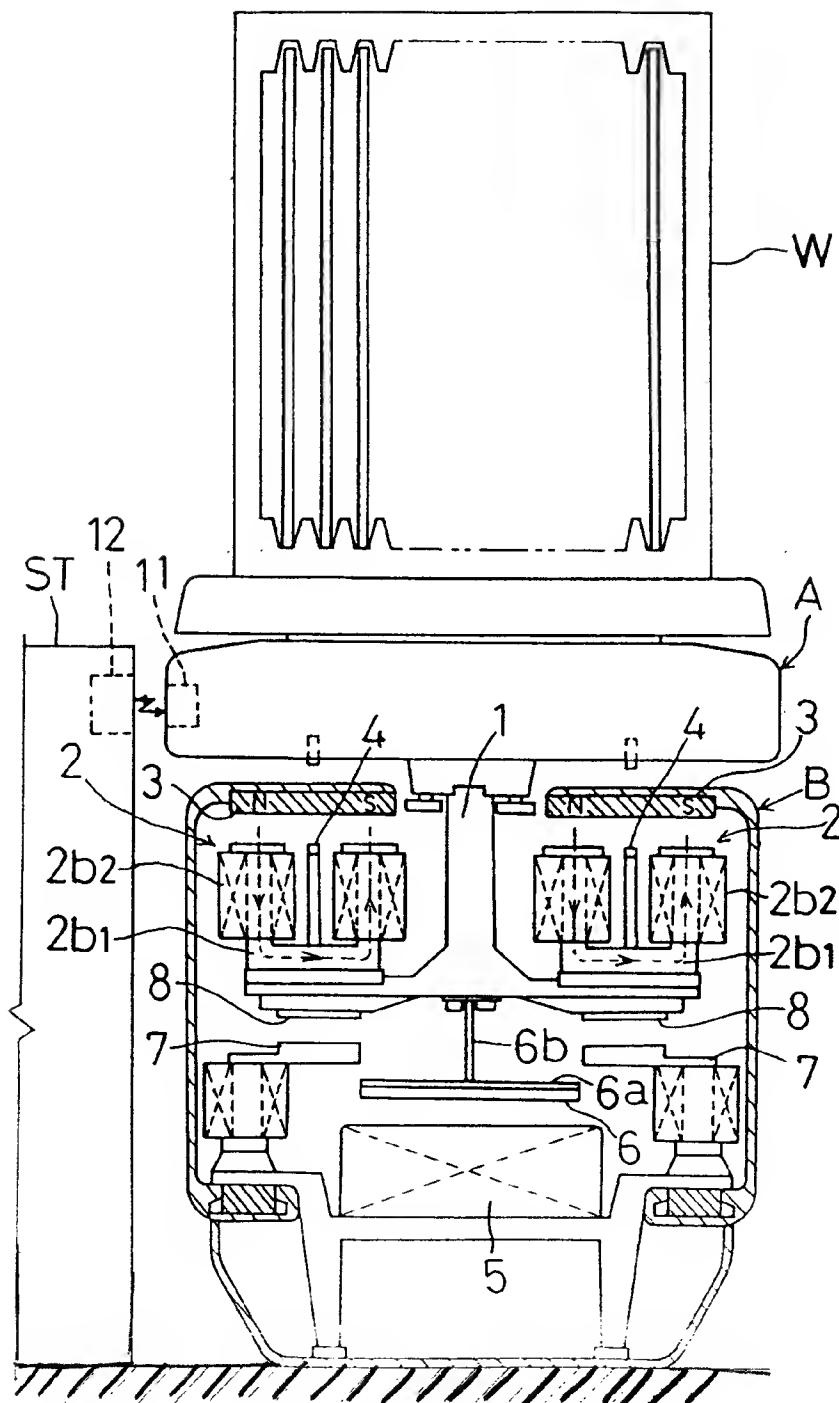


FIG 15

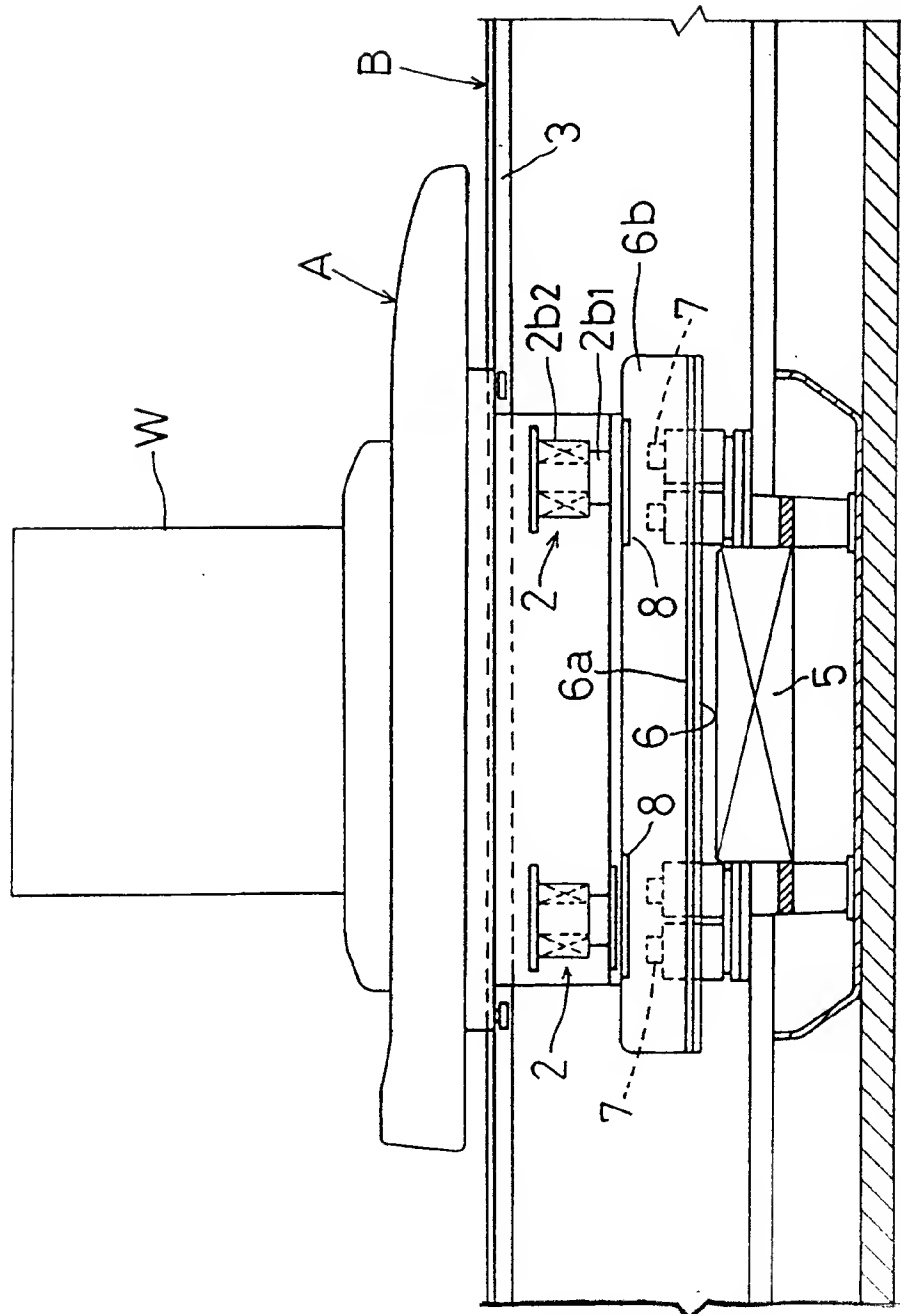




FIG 16

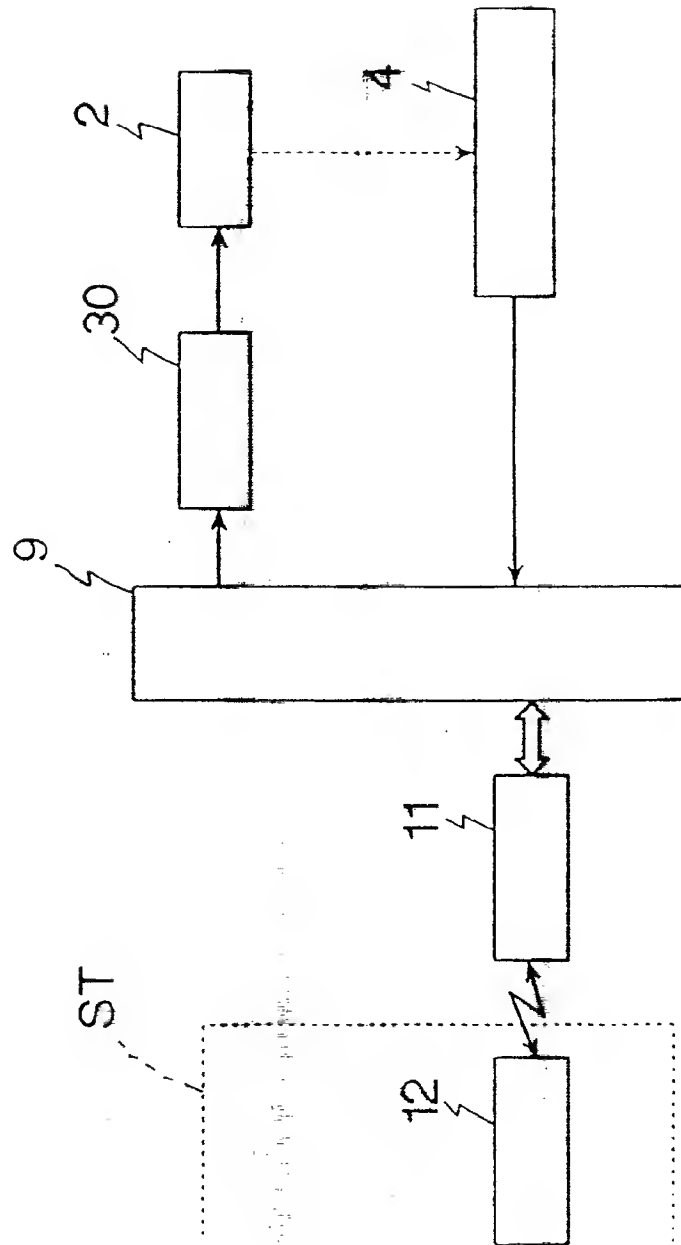


FIG 17

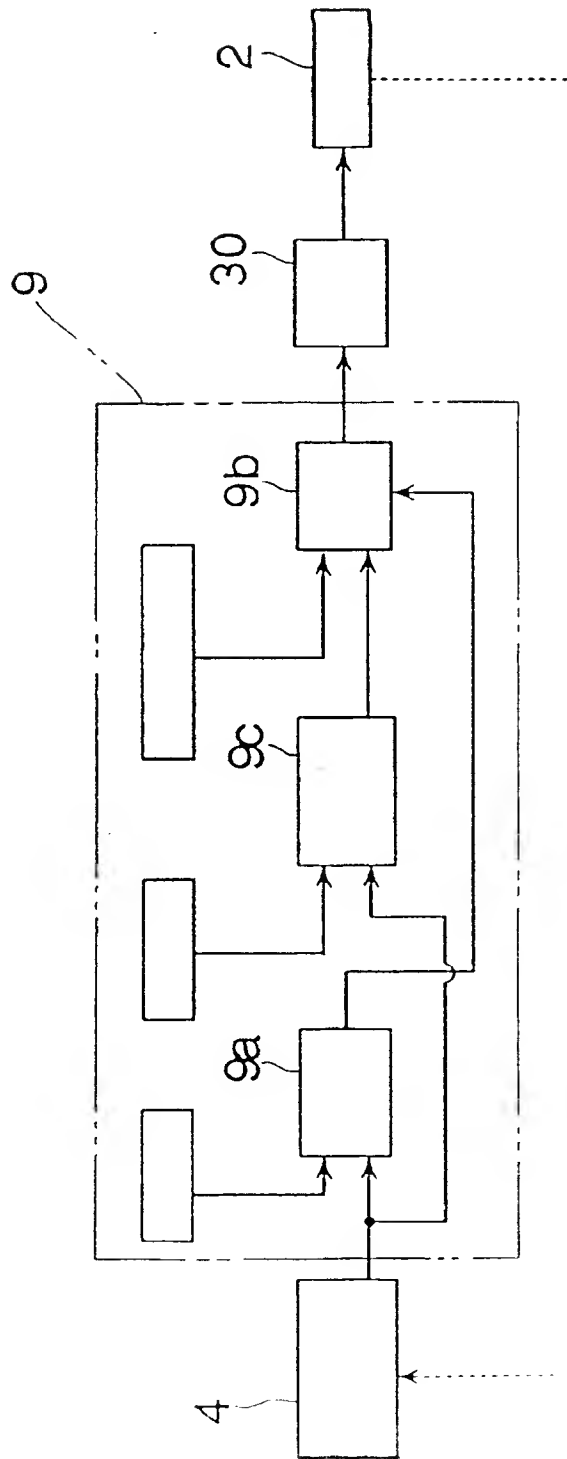


FIG 18

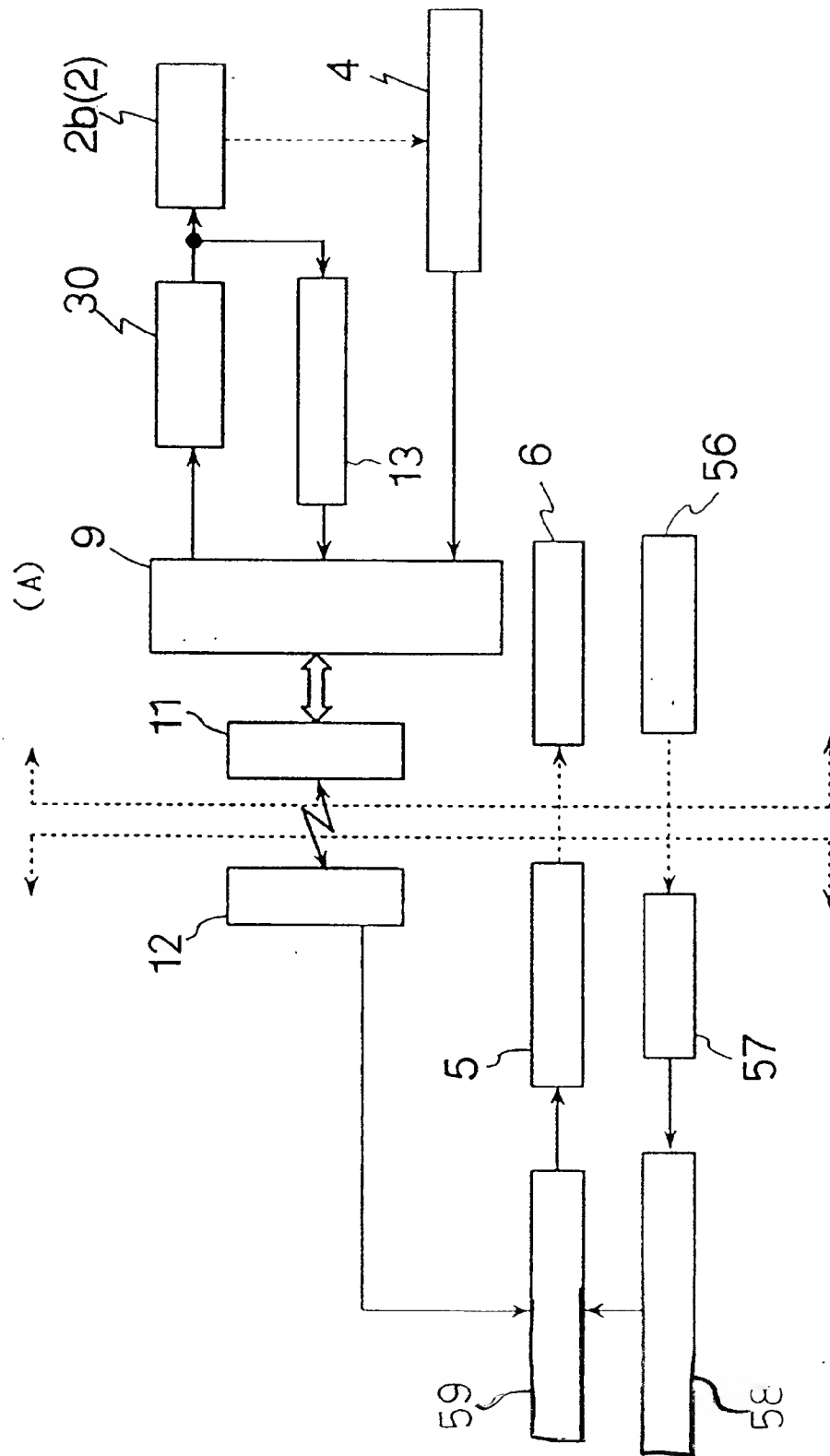


FIG 19

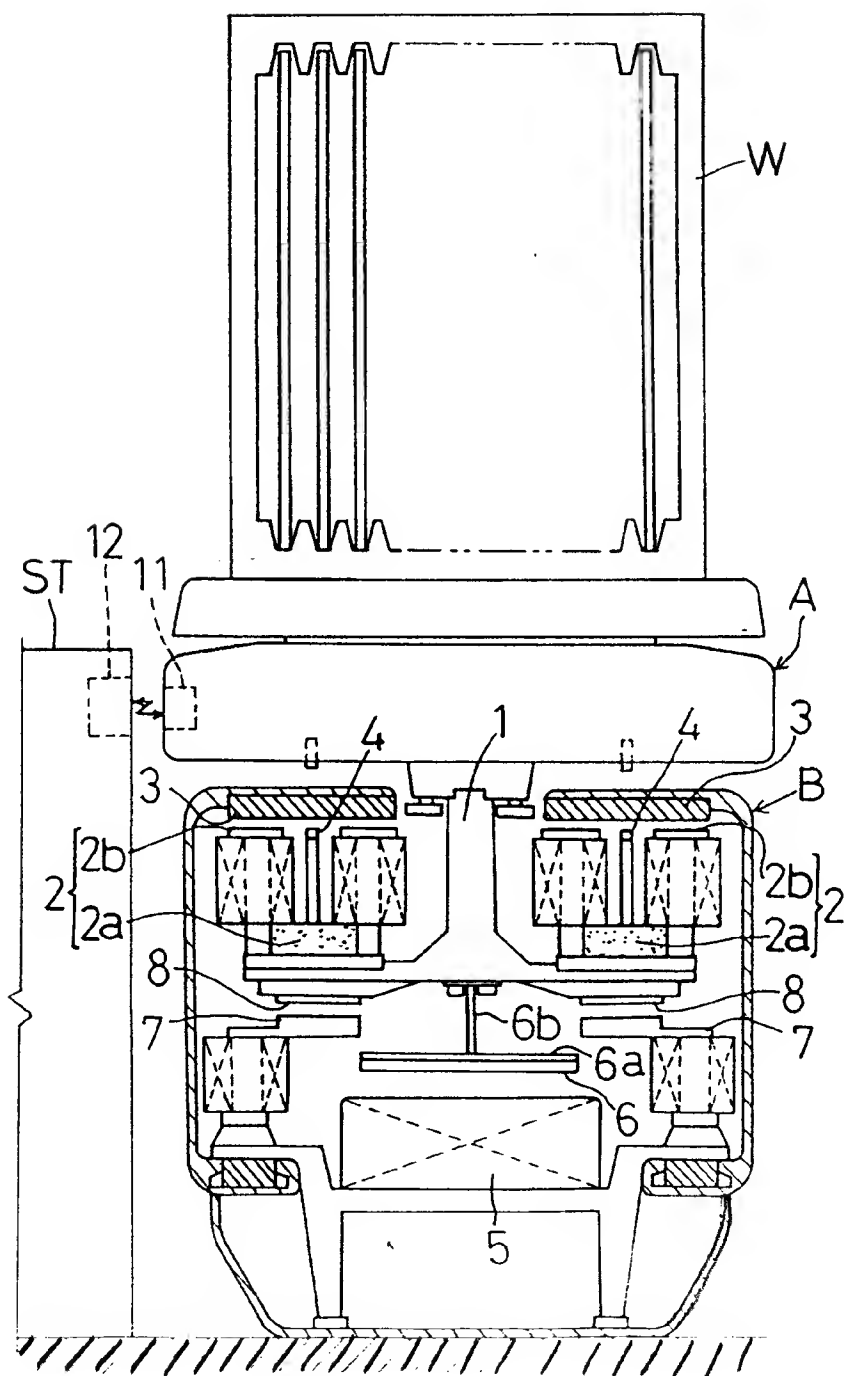


FIG 20

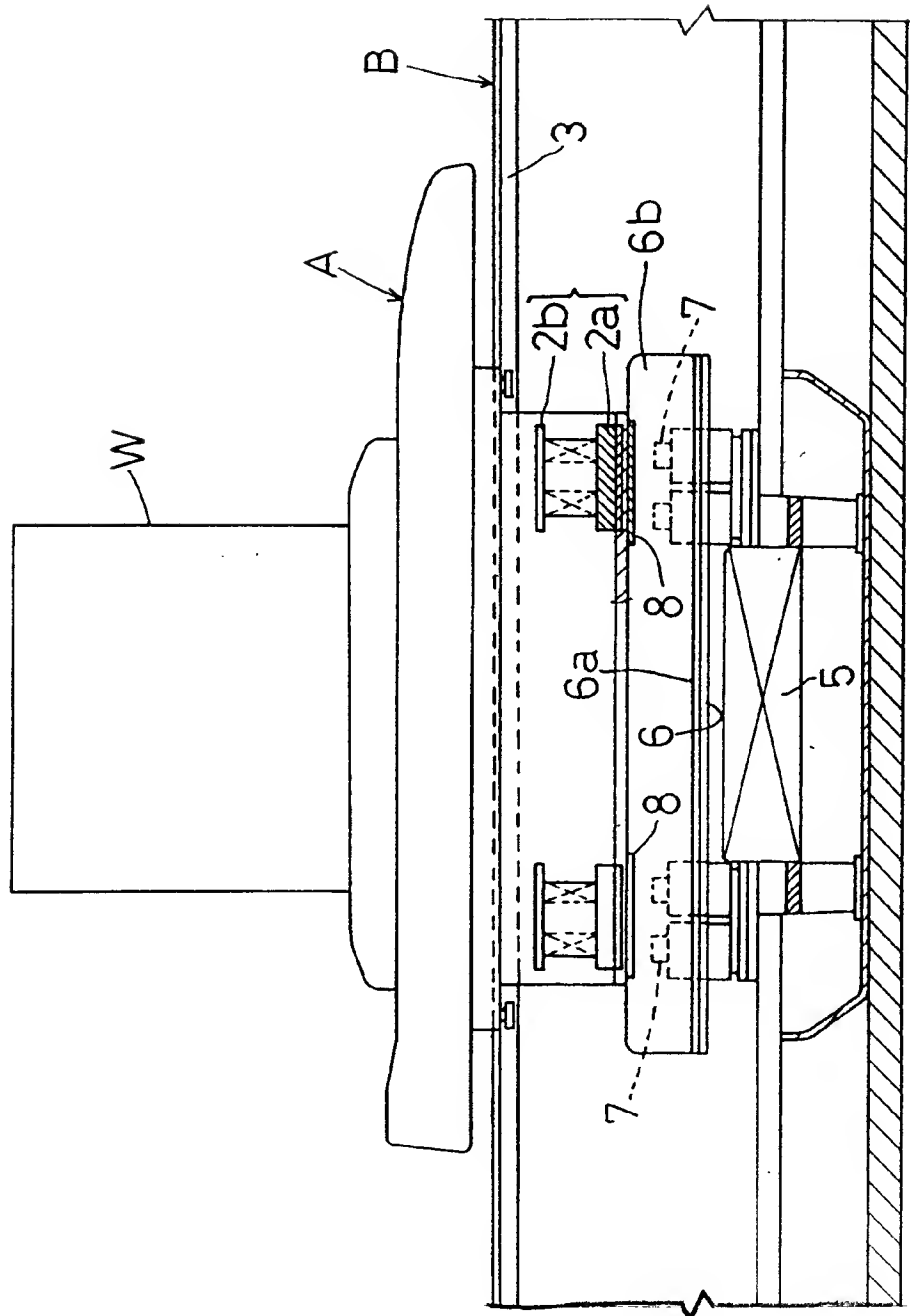


FIG. 21

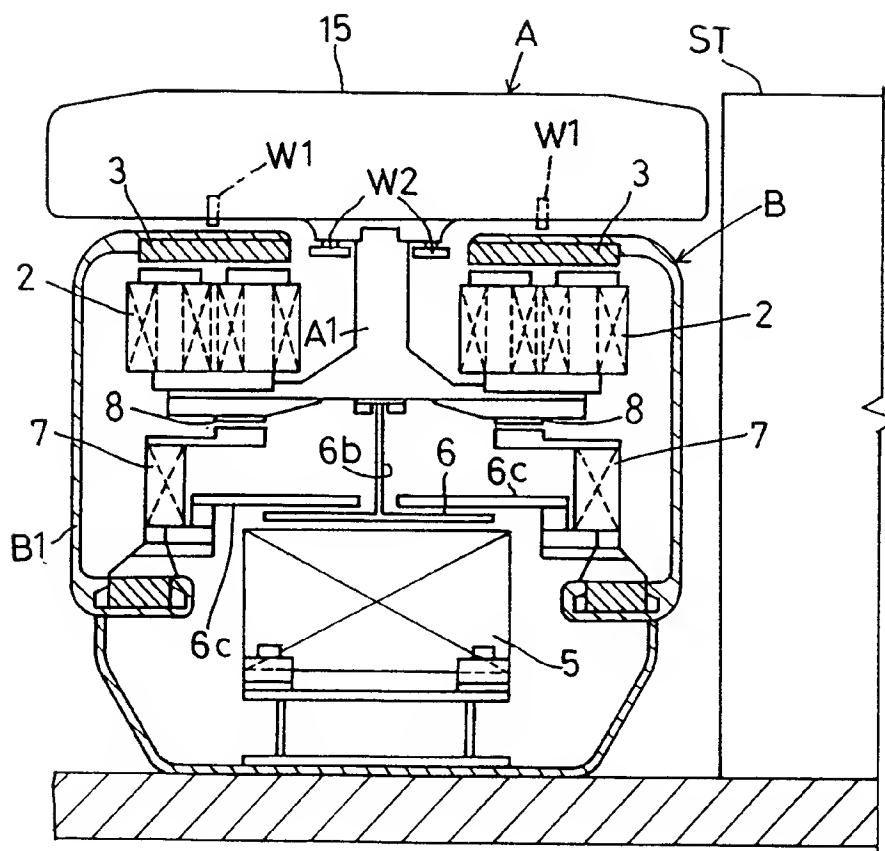


FIG. 22

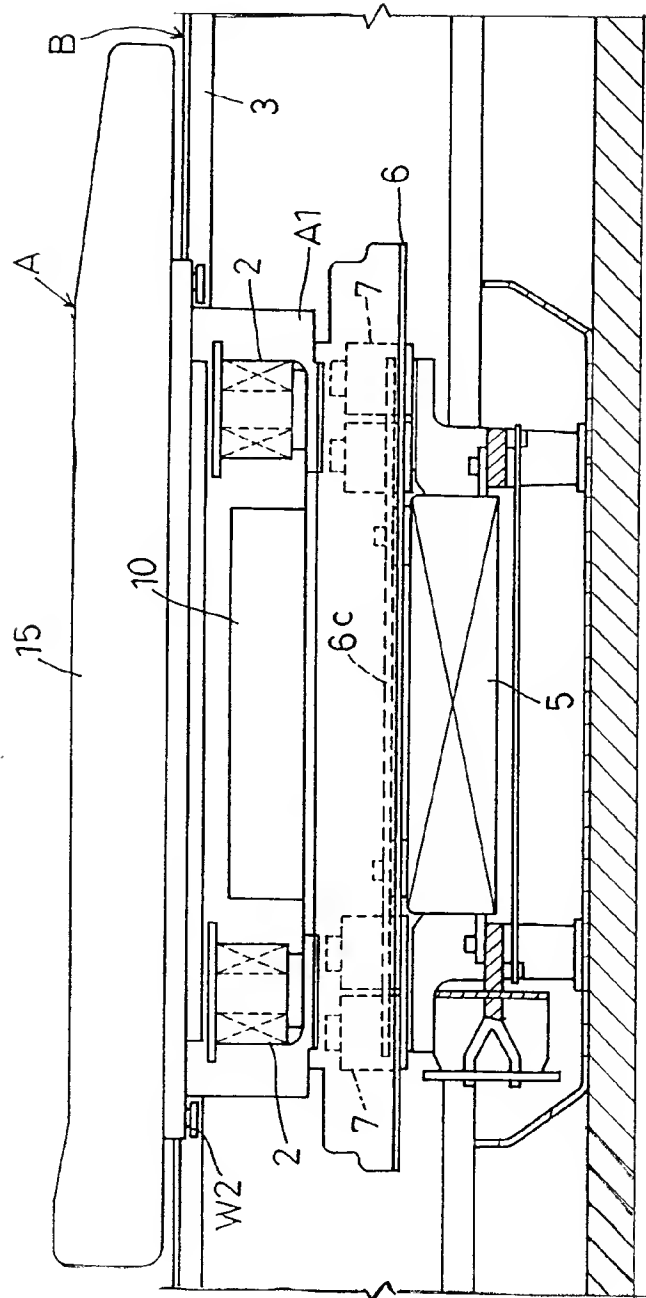
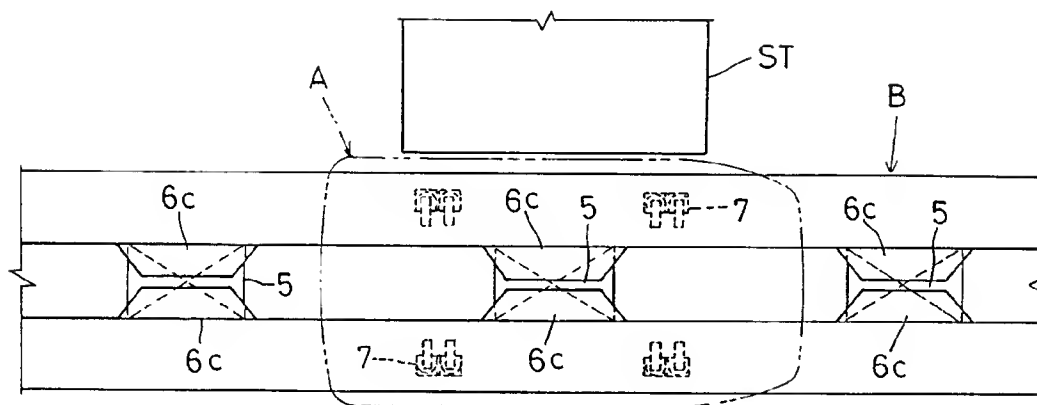


FIG. 23







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## EUROPEAN SEARCH REPORT

Application Number  
EP 93 11 1553

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
P,Y	WO-A-92 17929 (PIPER , JAMES , WILLIAM) 15 October 1992	1,9	B60L13/10 B60L5/00 B60L15/00 H02J5/00 B60L13/06
A	* abstract; figure 10 * * page 22 - page 23 * ---	4	
Y	40TH IEEE VEHICULAR TECHNOLOGY CONFERENCE May 1990 , ORLANDO, FLORIDA pages 100 - 104 MONOCHEHR EGHTEHADI 'INDUCTIVE POWER TRANSFER TO AN ELECTRICAL VEHICLE-ANALYTICAL MODEL-' * page 100 * ---	1,9	
Y	PROCEEDINGS OF THE FOURTH INTERSOCIETY ENERGY CONVERSION ENGINEERING CONFERENCE September 1969 , WASHINGTON, D.C. pages 778 - 794 E. J. WARD ET AL. 'GROUND TRANSPORTATION ENERGY TRANSFER' * page 783; figure 15 * ---	1,9	
Y	PATENT ABSTRACTS OF JAPAN vol. 016, no. 047 (M-1208)6 February 1992 & JP-A-03 251 003 (SUMITOMO ELECTRIC IND LTD) 8 November 1991 * abstract * ---	1,9	TECHNICAL FIELDS SEARCHED (Int.Cl.5)  B60L H02J
A	EP-A-0 246 098 (KABUSHIKI KAISHA TOSHIBA) 19 November 1987  * abstract; claims 1-10 * ---	6,7,9, 10,18, 19,24-26	
A	EP-A-0 179 188 (KABUSHIKI KAISHA TOSHIBA) 30 April 1986 * abstract * ---	25,26	
-/--			
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
THE HAGUE		28 October 1993	BOURBON, R
CATEGORY OF CITED DOCUMENTS		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application I : document cited for other reasons ----- & : member of the same patent family, corresponding document	
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			

EPO FORM 1503 03.92 (P04 C01)



European Patent  
Office

## EUROPEAN SEARCH REPORT

Application Number  
EP 93 11 1553

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
A	INTERNATIONAL CONFERENCE ON MAGLEV AND LINEAR DRIVES May 1987 , BALLY'S, LAS VEGAS pages 113 - 118 KARL DREIMANN 'THE M-BAHN MAGLEV RAPID TRANSIT SYSTEM - TECHNOLOGY, STATUS, EXPERIENCE -' * page 114 - page 115; figures 3,4 * ---	2,16-18	
A	US-A-5 058 505 (UEHIRA) 22 October 1991 * abstract * ---	20,22,23	
A	IEEE TRANSACTIONS ON VEHICULAR TECHNOLOGY vol. 38, no. 2 , May 1989 , NEW YORK US pages 102 - 108 XP99587 TERUO AZUKIZAWA 'A Linear Induction Motor Control System for Magnetically Levitated Carrier System' * figure 1 * ---	21	
A	PATENT ABSTRACTS OF JAPAN vol. 009, no. 092 (M-373)20 April 1985 & JP-A-59 216 401 (HITACHI SEISAKUSHO K.K.) 6 December 1984 * abstract * -----	1	TECHNICAL FIELDS SEARCHED (Int.Cl.5)
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 28 October 1993	Examiner BOURBON, R
<b>CATEGORY OF CITED DOCUMENTS</b> X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document  T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ----- & : member of the same patent family, corresponding document			

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EPO FORM 1503 (03/82) (P04/01)



**PCT**  
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Internationales Büro  
INTERNATIONALE ANMELDUNG VERÖFFENTLICHT NACH DEM VERTRAG ÜBER DIE  
INTERNATIONALE ZUSAMMENARBEIT AUF DEM GEBIET DES PATENTWESENS (PCT)

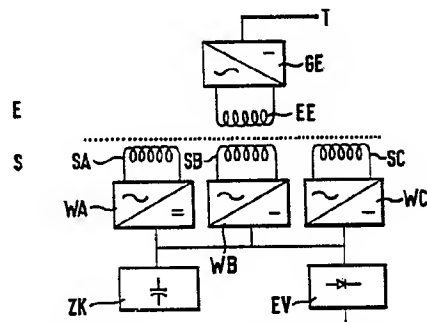
(51) Internationale Patentklassifikation <sup>5</sup> :  <b>B60L 13/02, 15/00</b>	<b>A1</b>	(11) Internationale Veröffentlichungsnummer: <b>WO 93/02888</b> (43) Internationales Veröffentlichungsdatum: 18. Februar 1993 (18.02.93)
(21) Internationales Aktenzeichen: PCT/EP92/01804 (22) Internationales Anmeldedatum: 7. August 1992 (07.08.92) (30) Prioritätsdaten: P 41 26 454.1 9. August 1991 (09.08.91) DE (71) Anmelder (für alle Bestimmungsstaaten ausser US): GRÜNDL UND HOFFMANN GESELLSCHAFT FÜR ELEKTROTECHNISCHE ENTWICKLUNGEN MBH [DE/DE]; Petersbrunner Str. 4, D-8130 Starnberg (DE). (72) Erfinder; und (75) Erfinder/Anmelder (nur für US) : HOFFMANN, Bernhard [DE/DE]; Jakob-Tresch-Str. 9, D-8130 Starnberg (DE). GRÜNDL, Andreas [DE/DE]; Haseneyst. 20, D-8000 München 70 (DE).		(74) Anwalt: KLUNKER, SCHMITT-NILSON, HIRSCH; Winzererstr. 106, D-8000 München 40 (DE). (81) Bestimmungsstaaten: CA, JP, US, europäisches Patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, SE). Veröffentlicht Mit internationalem Recherchenbericht.

(54) Title: SYNCHRONOUS LINEAR DRIVE WITH ELECTROMAGNETIC ENERGY TRANSFER

(54) Bezeichnung: SYNCHRON-LINEARANTRIEB MIT ELEKTROMAGNETISCHER ENERGIEÜBERTRAGUNG

(57) Abstract

In a synchronous linear motor, a field of travelling waves is generated in individual sections (SA, SB, SC) of a long stator opposite to an exciter part (EE) located on a vehicle. The field of travelling waves cooperates with the field generated in the exciter winding (EE) by direct current supply, so as to move forward the vehicle. The alternative current supplied to the stator section in order to generate the field of travelling waves induces practically no voltage in the exciter winding. In order to ensure an inductive energy transfer, a higher-frequency alternative current is superimposed on the alternative current available to generate the field of travelling waves. The higher-frequency alternative current induces a high-frequency voltage in the exciter winding that can be considered as the secondary winding of a transformer comprising the stator winding and the exciter winding. The high-frequency voltage can be decoupled by means of a passive or active rectifier (GE). This energy is available for auxiliary devices arranged in the vehicle and/or for supplying direct current to the exciter winding (EE).



(57) Zusammenfassung

Bei einem Synchron-Linearmotor wird in einem Langstator in einzelnen Abschnitten (SA, SB, SC) gegenüberliegend einem an einem Fahrzeug befindlichen Erregerteil (EE) ein Wanderfeld erzeugt, welches mit dem durch Gleichstromeinspeisung in die Erregerwicklung (EE) erzeugten Feld unter Vortrieb des Fahrzeugs zusammenwirkt. Dabei wird von dem zur Erzeugung des Wanderfelds in den Statorabschnitt eingespeisten Wechselstrom praktisch keine Spannung in der Erregerwicklung induziert. Zur induktiven Energieübertragung wird dem zur Erzeugung des Wanderfelds vorhandenen Wechselstrom ein höherfrequenter Wechselstrom überlagert, der in der Erregerwicklung, die als Sekundärwicklung eines die Statorwicklung und die Erregerwicklung umfassenden Transformators betrachtet werden kann, eine hochfrequente Spannung induziert, die über einen passiven oder aktiven Gleichrichter (GE) auskoppelbar ist. Diese Energie steht für Hilfseinrichtungen am Fahrzeug und/oder die Einspeisung von Gleichstrom in die Erregerwicklung (EE) zur Verfügung.

**LEDIGLICH ZUR INFORMATION**

Code, die zur Identifizierung von PCT-Vertragsstaaten auf den Kopfbögen der Schriften, die internationale Anmeldungen gemäss dem PCT veröffentlichen.

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## Synchron-Linearantrieb mit elektromagnetischer Energieübertragung

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Die Erfindung betrifft einen Synchron-Linearantrieb, mit einem vorzugsweise als am Fahrweg angeordneter Langstator ausgebildeten Stator mit Statorwicklungen zur Erzeugung eines Wanderfeldes für den Antrieb des bewegten Teils, und einem vorzugsweise am bewegten Teil vorhandenen Erregerteil mit gleichstromgespeister Erregerwicklung.

Synchron-Linearantriebe sind seit längerer Zeit bekannt (z.B. DE 22 57 773 C2). Der Stator ist hierbei üblicherweise als sogenannter Langstator ausgebildet, während das bewegte Teil, üblicherweise ein Fahrzeug zum Transport von Personen und/oder Gütern, eine Erregerwicklung trägt, in die ein Gleichstrom gespeist wird. Der Antrieb erfolgt mittels des in dem

-2-

Langstator erzeugten Wanderfeldes. Hierzu wird der Langstator vorzugsweise in Abschnitte mit mehrphasigen Wicklungen oder örtlich aufeinanderfolgenden Einphasenwicklungen unterteilt. Die Stromversorgung der Statorabschnitte erfolgt über Umrichter.

Die am Fahrzeug befindliche Erregerwicklung wird mit Gleichstrom gespeist.

Die oben geschilderte Anordnung läßt sich auch umkehren, so daß am bewegten Teil der Statoranführung zur Bereitstellung des den Vortrieb bewirkenden Wanderfeldes und die gleichstromgespeiste Erregerwicklung am Fahrweg angeordnet ist. Im folgenden soll aber zum einfachen Verständnis stets davon ausgegangen werden, daß der Stator als ortsfester Langstator ausgebildet ist, während sich der Erregerteil am bewegten Fahrzeug befindet.

Das Fahrzeug muß zur Bereitstellung des Erregerfeldes mit Energie versorgt werden. Die Energieversorgung kann über einen Schleifkontakt erfolgen, zu bevorzugen ist jedoch eine kontaktfreie Energieübertragung.

Es sind verschiedene Anordnungen für die berührungslose elektrische Energieübertragung mittels induktiv gekoppelter Wicklungen bekannt. Diese Energieübertragungseinrichtungen kann man als aufgeschnittenen Transformator betrachten, wobei jeweils eine Wicklung auf dem ortsfesten bzw. dem bewegten Teil vorhanden ist. Zwischen den relativ zueinander bewegten Teilen existiert zwangsläufig ein Luftspalt, der naturgemäß eine Verschlechterung der

-3-

für die Leistung kennzeichnenden Datenwerte bedingt, verglichen mit einem herkömmlichen Transformator. Die Hauptinduktivität bei der induktiven Kopplung zwischen ortsfestem und bewegtem Teil ist verhältnismäßig klein, die Streuinduktivitäten hingegen sind sehr groß. Dadurch ergibt sich ein relativ hoher Blindleistungsanteil.

Der bei einem Linearantrieb der hier in Rede stehenden Art üblicherweise notwendige Aufwand für eine herkömmliche induktive Energieübertragung zwischen Fahrweg und bewegtem Teil ist beträchtlich.

Der Erfindung liegt die Aufgabe zugrunde, einen Synchron-Linearantrieb der eingangs genannten Art anzugeben, bei dem mit vergleichsweise geringem zusätzlichen Aufwand elektrische Energie auf das bewegte Teil übertragen werden kann, wobei diese Energie entweder zur Bereitstellung des Gleichstroms für die Erregerwicklung oder für Zusatzeinrichtungen an dem bewegten Teil oder für beide Zwecke vorgesehen sein soll.

Bei einem Synchron-Linearantrieb der eingangs genannten Art wird diese Aufgabe erfindungsgemäß gelöst durch Mittel, mit denen dem in die Statorwicklungen eingespeisten, zur Vortriebskrafterzeugung dienenden Wechselstrom ein höherfrequenter Wechselstrom überlagert wird, und eine am Erregerenteil vorgesehene Einrichtung zum Auskoppeln der von dem höherfrequenten Wechselstrom in der Erregerwicklung induzierten Energie, oder Mittel, mit denen dem in die Erregerwicklung

-4-

eingespeisten Gleichstrom ein höherfrequenter Wechselstrom überlagert wird, und eine am Stator vorgesehene Einrichtung zum Auskoppeln der von dem höherfrequenten Wechselstrom induzierten Energie.

Der Begriff "höherfrequent" bedeutet hier, daß die Frequenz dieses höherfrequenten Wechselstroms wesentlich größer ist als die Frequenz des zur Vortriebskraft-erzeugung eingespeisten Wechselstroms. Die "höhere" Frequenz ist beispielsweise um das 10-fache höher als die Frequenz des Antriebs-Wechselstroms.

Synchron-Linearmotoren mit an dem bewegten Teil befindlicher Erregerwicklung haben die Eigenschaft, daß am Fahrzeug selbst keine Antriebs-Energieversorgung benötigt wird. Die für den Antrieb des bewegten Teils erforderliche Energie wird in die Statorwicklung eingespeist. In die Erregerwicklung am bewegten Teil muß lediglich die zur Erregung erforderliche Energie eingespeist werden. Erfindungsgemäß nutzt man die bei einem Synchron-Linearmotoren ohnehin vorhandenen Grundelemente auch für die Übertragung von Energie mit aus.

Bekanntlich wird bei einem Synchron-Linearmotor im Stator ein mehrphasiger Drehstrom oder mehrere einphasige, zueinander phasenversetzte Wechselströme benötigt, die in die Wicklung bzw. Wicklungen eingespeist werden, um ein Wanderfeld für den Vortrieb des Fahrzeugs zu erzeugen. Diesem Wechselstrom wird erfindungsgemäß der höherfrequente Wechselstrom überlagert. Er wird von den ohnehin



-5-

vorhandenen Einrichtungen für die Einspeisung des Statorstroms bereitgestellt.

Von dem zur Vortriebskraft erzeugten Wanderfeld wird in der Erregerwicklung keine Spannung induziert. Lediglich der höherfrequente Wechselstrom wirkt transformatorisch auf die Erregerwicklung. Damit kann aus der Erregerwicklung Energie ausgekoppelt werden. Diese Energie kann - wie gesagt - zur Einspeisung von Gleichstrom in die Erregerwicklung genutzt werden, und/oder man kann mit der aus der Erregerwicklung ausgekoppelten Energie andere Einrichtungen am Fahrzeug speisen.

Durch den höherfrequenten Stromanteil ergeben sich entsprechenden Änderungen des Induktionsflusses durch die Erregerwicklung.

Bei einem Synchron-Linearmotor werden erfindungsgemäß als Mittel zur Einspeisung des höherfrequenten Wechselstroms die zur Statorstromeinspeisung ohnehin vorhandenen Wechselrichteranordnungen verwendet.

Wenn sich das bewegte Teil des Synchron-Linearantriebs, im folgenden auch als "Fahrzeug" bezeichnet, entlang dem Langstator bewegt, befindet sich die Erregerwicklung des Fahrzeugs stets in einer neuen Lage gegenüber dem Stator. Es existiert also eine periodische Kopplung zwischen der Statorwicklung und der Erregerwicklung. Die üblichen Synchron-Linearantriebe sind aber ohnehin mit einer mehrphasigen Statorwicklung versehen, damit der Antrieb

-6-

praktisch in jeder beliebigen Position des Fahrzeugs wirksam und gleichmäßig ist. Damit ist es erfindungsgemäß auch möglich, eine unterbrechungsfreie Energieübertragung entlang dem mehrphasigen Statorwicklungen tragenden Stator zu erhalten.

Nach jeder Bewegung des Fahrzeugs um einen der Phasenzahl entsprechenden Bruchteil der Polteilung des Stators existiert eine optimale Kopplung zwischen einer Phasenwicklung und der Erregerwicklung. Es ist also praktisch zu jedem Zeitpunkt über eine der Phasenwicklungen eine Energieübertragung möglich.

Zum Einstellen des Statorstroms sind üblicherweise Wechselrichter vorhanden, die abhängig von der Lage des Fahrzeugs einzelne Abschnitte des Stators versorgen. Erfindungsgemäß werden diese Wechselrichter auch zur Einspeisung des höherfrequenten Wechselstroms verwendet. Wie oben erwähnt, sind bei üblichen Synchron-Linearantrieben mehrere Statorabschnitte vorgesehen, so daß lediglich nur in den Statorabschnitt Strom eingespeist wird, in welchem sich das Fahrzeug befindet. Erfindungsgemäß sind nun die einzelnen Abschnitte vorzugsweise nicht länger als der Erregerabschnitt des bewegten Teils (Fahrzeugs). Ist der Statorabschnitt wesentlich länger als der Erregerabschnitt, so sinkt, bei vorgegebener maximaler Blindleistung, die übertragene Nutzleistung. Eine günstige Energieübertragung ergibt sich dann, wenn man eine Einzelspeisung von hinreichend kurzen Statorabschnitten vorsieht, so daß der nicht vom Erregerteil überlappte Längenabschnitt nur geringen Einfluß auf die

-7-

Energieübertragung hat.

Nach der ersten Alternative wird also der höherfrequente Wechselstrom dem Antriebs-Wechselstrom überlagert. Alternativ wird der höherfrequente Wechselstrom dem in die Erregerwicklung eingespeisten Gleichstrom überlagert, wobei dann die Einrichtung zum Auskoppeln der über den höherfrequenten Wechselstrom induzierten Energie am Stator vorgesehen ist. Die Erregerwicklung kann an der Strecke vorgesehen sein, während der Stator sich am Fahrzeug befindet. In letztgenanntem Fall umfassen die Mittel zur Einspeisung oder Auskopplung des höherfrequenten Wechselstroms die zur Erregerstromeinspeisung vorgesehene Pulsstromrichteranordnung.

Im Erregerteil sind zur Führung des magnetischen Flusses zweckmäßigerweise Eisenelemente vorgesehen. Um Wirbelstromverluste zu vermeiden, werden diese Eisenelemente z.B. als geblechte Elemente ausgeführt.

Ausgehend von dem Zustand, bei dem in der Erregerwicklung durch den höherfrequenten Wechselstromanteil im Stator eine Spannung induziert ist, muß die eingekoppelte Energie aus der Erregerwicklung am Fahrzeug ausgekoppelt werden.

Hierzu sieht die Erfindung in einer ersten, passiven, Anordnung vor, daß zum Auskoppeln im Erregerteil eine Gleichrichteranordnung vorgesehen ist, und daß gegebenenfalls zur Einspeisung des Erregergleichstroms ein Stellglied vorgesehen ist. Es handelt sich im Prinzip um einen üblichen Gleichrichter. Die jetzt

-8-

auf der Erregerseite erforderliche Blindleistung, bedingt durch sekundärseitige Streuinduktivitäten und anteilige Hauptinduktivität, von der Seite des Stators bereitgestellt und über den Luftspalt übertragen werden.

Es ist effizienter, die erregerseitig erforderliche Blindleistung auch auf der Seite des Erregers zu erzeugen. Bezogen auf das Bild des aufgeschnittenen Transformators heißt dies, daß Blindleistung anteilig sekundärseitig erzeugt werden soll, um den Gesamt-Blindleistungsanteil zu minimieren. Im Extremfall wird unter Inkaufnahme erhöhter Gesamtblindleistung die Blindleistung ausschließlich erregerseitig erzeugt. Dadurch reduziert man den streckenseitigen Installationsaufwand.

Eine dieses leistende Auskoppelinrichtung auf der Seite des Erregerteils enthält einen Pulsstromrichter zur Einstellung des Erregergleichstroms. Dies bedeutet im Gegensatz zu der oben angesprochenen passiven Gleichrichtung eine "aktive" Gleichrichtung. Der Pulsstromrichter übernimmt sowohl die Gleichrichtung des induzierten höherfrequenten Stromanteils als auch die Einstellung des Gleichstroms, der in die Erregerwicklung eingespeist wird.

Der für die Energieübertragung benötigte, höherfrequente Wechselstrom wird durch das Zwischentakten des Wechselrichters erzeugt. Hierbei ist zu beachten, daß das von dem Pulsstromrichter bewirkte Zwischentakten synchron und phasenrichtig zu der von der Statorseite induzierten Spannung ist.

Erfindungsgemäß erfolgt die Einspeisung des höherfrequenten Wechselstroms in die Statorwicklungen mit einer um  $180^\circ$  umschaltbaren Phasenlage. Bei einer einphasigen, von einem Stromrichter gespeisten Erregerwicklung muß der höherfrequente Wechselstrom gleichphasig auf die Erregerwicklung wirken, damit keine gegenseitige Auslöschung stattfindet. Bei jedem Polwechsel im Erregerteil muß der höherfrequente Wechselstrom der Statorwicklung in der Phase um  $180^\circ$  gedreht werden. Dann aber sind Frequenz und Phasenlage der Spannungen in der Erregerwicklung unabhängig von der Bewegung des Fahrzeugs gegenüber dem Stator.

In der Erregerwicklung addieren sich die höherfrequenten Anteile aus räumlich versetzten und verschiedene Phasen aufweisenden Statorwicklungen. Damit erfolgt eine lückenlose Energieübertragung.

Durch die aktive Gleichrichtung am Erregerteil läßt sich die Flußrichtung der Leistung umkehren, d. h. man kann Energie vom Fahrzeug in den Stator einkoppeln.

Grundsätzlich läßt sich die zu übertragende Wirkleistung durch entsprechende Einstellung des Phasenwinkels zwischen der erregerseitigen Taktfrequenz und der statorseitigen Taktfrequenz einstellen.

Wie oben ausgeführt, erfolgt die Energieübertragung bei einem Synchron-Linearmotor durch höherfrequenten Wechselstrom vom Stator auf die Erregerwicklung im bewegten Teil (Fahrzeug). Hierzu werden statorseitig die ohnehin vorhandenen Einzelwicklungen oder Mehrphasen-Wicklungen und die zu einzelnen Stator-

-10-

abschnitten gehörigen Wechselrichteranordnungen verwendet. Darüber hinaus kann man auch gesonderte Stromrichter, Generatoren und dergleichen vorsehen, die unabhängig von den für den Antrieb vorhandenen Bauteilen sind.

Durch die Erfindung ist also eine vom Stator zum Erregerteil oder umgekehrt gerichtete Leistungsübertragung möglich, wobei vorzugsweise die für den Antrieb ohnehin vorhandenen Bauelemente genutzt werden.

Im folgenden wird ein Ausführungsbeispiel der Erfindung anhand der Zeichnung näher erläutert.

Es zeigen:

Figur 1 eine schematische Darstellung des Stromverlaufs in der Statorwicklung und der Erregerwicklung eines Synchron-Linear-motors

Figur 2 eine schematische Darstellung eines Erregerteils am Fahrzeug eines Synchron-Linearantriebs sowie eines dem Erregerteil gegenüberliegenden Statorabschnitts

Figur 3 ein Prinzipschaltbild eines Synchron-Linearantriebs mit einer Einrichtung zum induktiven Einspeisen von Energie in den Erregerteil

Figur 3 zeigt schematisch die Anordnung eines Synchron-Linearantriebs mit einem unterhalb der gestrichelten Linie allgemein dargestellten Langstator S, bestehend aus mehreren hintereinander angeordneten Statorabschnitten mit jeweils einer Statorwicklung SA, SB und SC, die ihrerseits jeweils mit einem Wechselrichter WA, WB bzw. WC verbunden sind. Die Wechselrichter werden von einer Energieversorgung EV über einen Zwischenkreis ZK gespeist. Dabei werden die Statorwicklungen der einzelnen Abschnitte von einer nicht dargestellten Steuerung derart angesteuert, daß lediglich die Statorwicklung mit Strom gespeist wird, über der sich die Erregerwicklung EE des Fahrzeugs befindet. Im Erregerteil ist die Erregerwicklung EE an einen

-12-

Gleichrichter GE angeschlossen, an dessen Ausgang Energie ausgekoppelt werden kann. Diese Energie steht für verschiedene Hilfseinrichtungen am Fahrzeug des Synchron-Linearantriebs zur Verfügung. Alternativ oder zusätzlich steht die in die Erregerwicklung EE induktiv eingekoppelte Energie als Speiseenergie für die Erregerwicklung zur Verfügung.

Zur Erregung wird in die Erregerwicklung ein Gleichstrom eingespeist. Das Wanderfeld wird durch die Einzelwicklung des Stators, also hier die Statorwicklungen SA, SB und SC, erzeugt.

Die Wechselrichter WA, WB und WC sowie die daran angeschlossene, nicht dargestellte Steuerung bewirken außer der Erzeugung eines Wanderfelds, daß dem zur Erzeugung des Wanderfelds dienenden, eine relativ niedrige Frequenz aufweisenden Wechselstrom ein höherfrequenter Wechselstrom überlagert wird. Während der niederfrequente Wechselstrom lediglich zur Bereitstellung der Energie für die Vortriebskraft dient, in der Erregerwicklung EE jedoch keine Spannung induziert, dient der höherfrequente Wechselstromanteil zum Induzieren einer Spannung in der Erregerwicklung EE, die man als Sekundärwicklung eines Transformator betrachten kann, der aus jeweils einer Statorwicklung, hier der Statorwicklung SB, und der Erregerwicklung EE sowie dem dazwischen befindlichen Luftspalt besteht.



-13-

Figur 1 zeigt den Stromverlauf in der Statorwicklung (unterer Verlauf) und in der Erregerwicklung (oberer Verlauf). Man erkennt, daß dem niederfrequenten Wechselstrom, der für den Vortrieb in die einzelnen Statorwicklungen eingespeist wird, ein höherfrequenter Wechselstrom überlagert ist. Dieser höherfrequente Wechselstrom sorgt für die induktive Einkopplung von Energie in die Erregerwicklung. Dort wird ein Wechselstrom induziert, der lediglich durch die Grundwelle des zur Erzeugung des Wanderfeldes bereitgestellten, niederfrequenten Wechselstroms verstimmt ist.

Figur 2 zeigt schematisch einen Teil des Stators S und den Erregerteil E. Der Erregerteil wird in Figur 2 nach links bewegt, indem im Stator S ein Wanderfeld und im Erregerteil ein statisches Magnetfeld durch Gleichstromeinspeisung erzeugt wird.

Gemäß der Darstellung in Figur 2 stehen sich am Erregerteil ein Pol E1 und am Stator ein Pol S2 gegenüber. In diesem Bereich erfolgt eine optimale Einkopplung des höherfrequenten Anteils seitens des Stators in die Erregerwicklung. Es erfolgt auch eine Kopplung zwischen S1 und E2, diese ist jedoch schwächer, wird aber mit zunehmender Annäherung zwischen S1 und E2 stärker. Durch positionsabhängige Phasenumschaltung des höherfrequenten, zur Energieübertragung dienenden Wechselstroms wird erreicht, daß in der Erregerwicklung stets ein gleichphasiger Wechselstrom induziert wird, sich die Anteile aus den einzelnen

Bereichen also addieren.

Die in Figur 2 dargestellten Elemente sind bei einem üblichen Synchron-Linearmotor ohnehin vorhanden.

In einer abgewandelten Ausführungsform der Erfindung können zusätzlich zu den bei einem Synchron-Linearmotor ohnehin vorhandenen Elementen zusätzliche Wicklungen vorgesehen sein, insbesondere Wicklungen am Erregerteil.

Der in Figur 3 schematisch dargestellte Gleichrichter GE dient als sogenannter aktiver Gleichrichter. Außer der Funktion, den höherfrequenten Wechselstrom, der in die Erregerwicklung induziert wird, gleichzurichten, hat der Gleichrichter außerdem noch die Funktion, den in die Erregerwicklung einzuspeisenden Gleichstrom einzustellen. Durch entsprechende Einstellung des Energieflusses läßt sich auch eine umgekehrte Energieübertragung erreichen, also eine Übertragung von Energie von dem Erregerteil E in den Stator S.

Bei einer weiteren Ausführungsform der Erfindung sind die oben erläuterten und in Figur 3 skizzierten Verhältnisse umgekehrt: Der "Stator" befindet sich am Fahrzeug, während sich an der Strecke Erregerwicklungen befinden. Das Wanderfeld wird dann am Fahrzeug erzeugt.

P a t e n t a n s p r ü c h e

1. Synchron-Linearantrieb, mit einem vorzugsweise als am Fahrweg angeordneter Langstator ausgebildeten Stator mit Statorwicklungen zur Erzeugung eines Wanderfeldes für den Antrieb des bewegten Teils, und einem vorzugsweise am bewegten Teil vorhandenen Erregerteil mit gleichstromgespeister Erregerwicklung (EE),  
g e k e n n z e i c h n e t d u r c h  
Mittel (WA, WB, WC), mit denen dem in die Statorwicklungen (SA, SB, SC) eingespeisten, zur Vortriebskrafterzeugung dienenden Wechselstrom ein höherfrequenter Wechselstrom überlagert wird, und eine am Erregerteil vorgesehene Einrichtung (GE, T) zum Auskoppeln der von dem höherfrequenten Wechselstrom in der Erregerwicklung induzierten Energie, oder Mittel, mit denen dem in die Erregerwicklung eingespeisten Gleichstrom ein höherfrequenter Wechselstrom überlagert wird, und eine am Stator vorgesehene Einrichtung zum Auskoppeln der von dem höherfrequenten Wechselstrom induzierten Energie.
2. Synchron-Linearantrieb nach Anspruch 1, bei dem die Mittel zur Einspeisung oder Auskopplung des höherfrequenten Wechselstroms die zur Statorstromeinspeisung vorgesehene Wechselrichteranordnung (WA, WB, WC) umfassen.
3. Synchron-Linearantrieb nach Anspruch 1, bei dem die Mittel zur Einspeisung oder Auskopplung des höherfrequenten Wechselstroms die zur Erregerstromeinspeisung vorgesehene Pulsstromrichteranordnung umfassen.

-16-

4. Synchron-Linearantrieb nach Anspruch 1, 2 oder 3,  
bei dem in dem Stator abschnittsweise dort,  
wo sich die Erregerwicklung (EE) befindet, Strom  
eingespeist wird, wobei die einzelnen Abschnitte  
(SA, SB, SC) vorzugsweise hinreichend kurz sind, so  
daß der nicht vom Erregerteil überlappte Längenab-  
schnitt nur geringen Einfluß auf die Energieübertragung  
hat.
5. Synchron-Linearantrieb nach einem der Ansprüche  
1 bis 4,  
dadurch gekennzeichnet,  
daß die in der Erregerwicklung (EE) durch den  
höherfrequenten Wechselstrom induzierte Energie  
zur Gleichstromspeisung der Erregerwicklung (EE)  
verwendet wird.
6. Synchron-Linearantrieb nach einem der Ansprüche  
1 bis 5,  
dadurch gekennzeichnet,  
daß die in der Erregerwicklung durch den höher-  
frequenten Wechselstrom induzierte Energie zur  
Versorgung von an dem bewegten Teil befindlichen  
Hilfseinrichtungen verwendet wird.
7. Synchron-Linearantrieb nach Anspruch 1 und 3,  
dadurch gekennzeichnet,  
daß die durch den höherfrequenten Wechselstrom in den  
Stator induzierte Energie zur Erzeugung des Wander-  
feldstroms verwendet wird.

-17-

8. Synchron-Linearantrieb nach einem der Ansprüche  
1 bis 7,

d a d u r c h g e k e n n z e i c h n e t ,  
daß zur Auskopplung im Erregerteil eine Gleich-  
richteranordnung (GE) vorgesehen ist, und daß zur  
Einspeisung des Erregergleichstroms ein Stellglied  
vorgesehen ist.

9. Synchron-Linearantrieb nach einem der Ansprüche  
1 bis 7,

d a d u r c h g e k e n n z e i c h n e t ,  
daß zur Auskopplung im Erregerteil ein Pulsstrom-  
richter vorgesehen ist, der den höherfrequenten  
induzierten Stromanteil gleichrichtet und den  
Gleichstrom für die Erregerwicklung einstellt.

10. Synchron-Linearantrieb nach einem der Ansprüche  
1 bis 9,

d a d u r c h g e k e n n z e i c h n e t ,  
daß die Einspeisung des höherfrequenten Wechsel-  
stroms in die Statorwicklungen (SA, SB, SC) mit  
einer 180°-Phasenumschaltung erfolgt.

11. Synchron-Linearmotor nach einem der Ansprüche  
1 bis 10,

d a d u r c h g e k e n n z e i c h n e t ,  
daß die Auskoppeleinrichtung an die Erregerwicklung  
angeschlossen ist.

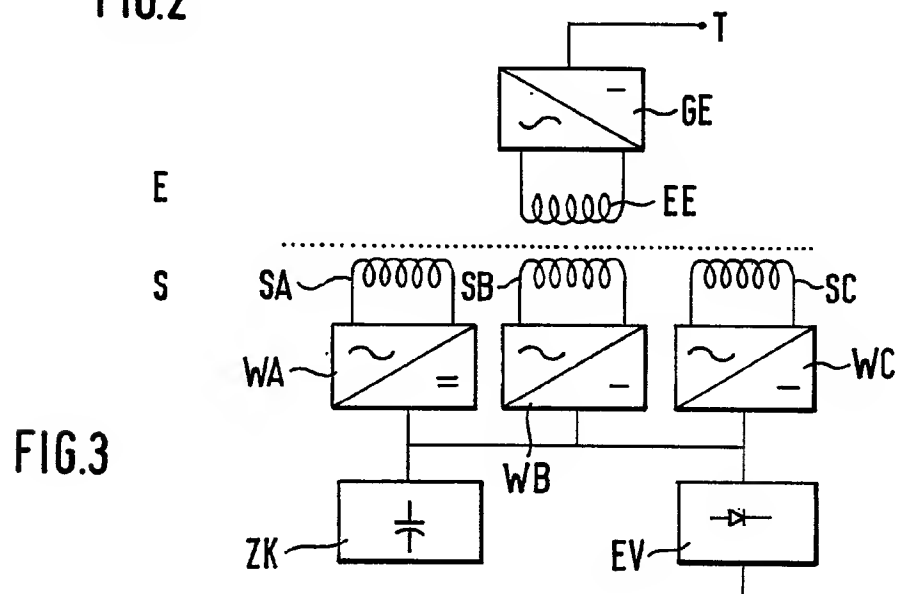
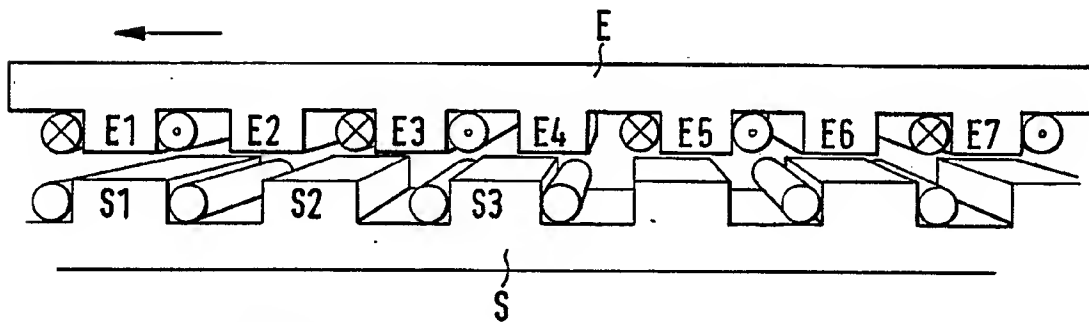
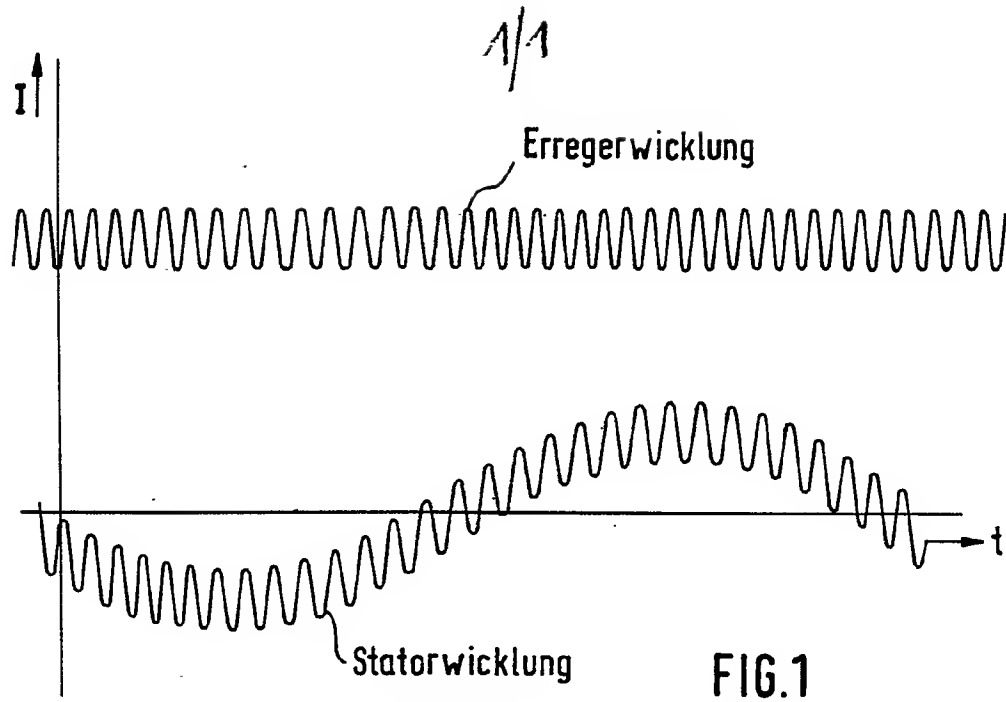
12. Synchron-Linearantrieb nach einem der Ansprüche  
1 bis 10,

d a d u r c h g e k e n n z e i c h n e t ,  
daß im Erregerteil zusätzliche Wicklungen für die

-18-

induktive Energieübertragung vorhanden sind.

13. Synchron-Linearantrieb nach einem der Ansprüche  
1 bis 12,  
dadurch gekennzeichnet,  
daß am Stator zusätzliche Speise- und Kuppelvor-  
richtungen für die Energieübertragung vorhanden sind.



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/ EP 92/01804

## A. CLASSIFICATION OF SUBJECT MATTER

Int.Cl.5 B60L13/02; B60L15/00

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int.Cl.5 B60L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
P,A	IEEE TRANSACTIONS ON MAGNETICS Vol. 28, No. 1, January 1992, NEW YORK US pages 474 - 477, XP000258042 M.SHIBATA ET AL. 'On-Board Power Supply System of a Magnetically Levitated Vehicle' see the whole document	1
A	DE, A, 2 257 773 (WEH HERBERT) 30 May 1974 cited in the application see page 12 - page 13	1
A	DE, A, 2 423 579 (SIEMENS AG) 27 November 1975 see page 4 - page 8	1,6

☐ Further documents are listed in the continuation of Box C.
 ☐ See patent family annex.

## \* Special categories of cited documents:

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"P" document published prior to the international filing date but later than the priority date claimed

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"&" document member of the same patent family

Date of the actual completion of the international search

1 October 1992 (01.10.92)

Date of mailing of the international search report

27 October 1992 (27.10.92)

Name and mailing address of the ISA/

EUROPEAN PATENT OFFICE

Facsimile No.

Authorized officer

Telephone No.



# INTERNATIONAL SEARCH REPORT

International application No.

PCT/EP 92/01804

## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	<p>JOURNAL OF THE INSTITUTION OF ELECTRICAL ENGINEERS  Vol. 121, No. 11R, November 1974, STEVENAGE GB  pages 1224 - 1248  A.J.ELLISON ET AL. 'Surface-guided transport systems of the future'  see page 1238, paragraph 5.2  see page 1240, paragraph 6  -----</p>	1

**ANNEX TO THE INTERNATIONAL SEARCH REPORT  
ON INTERNATIONAL PATENT APPLICATION NO. EP 9201804  
SA 63096**

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.  
The members are as contained in the European Patent Office EDP file on  
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information. 01/10/92

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE-A-2257773	30-05-74	None	
DE-A-2423579	27-11-75	None	

EPO FORM P0479

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

**I. KLASSEFIZIKATION DES ANMELDUNGS-GEGENSTANDS** (bei mehreren Klassifikationssymbolen sind alle anzugeben)<sup>6</sup>

Nach der Internationalen Patentklassifikation (IPC) oder nach der nationalen Klassifikation und der IPC

Int.Kl. 5 B60L13/02; B60L15/00

**II. RECHERCHIERTE SACHGEBIETE**Recherchierter Mindestprüfstoff <sup>7</sup>

Klassifikationssystem	Klassifikationssymbole
Int.Kl. 5	B60L

Recherchierte nicht zum Mindestprüfstoff gehörende Veröffentlichungen, soweit diese unter die recherchierten Sachgebiete fallen <sup>8</sup>**III. EINSCHLAGIGE VERÖFFENTLICHUNGEN <sup>9</sup>**

Art. <sup>9</sup>	Kennzeichnung der Veröffentlichung <sup>11</sup> , soweit erforderlich unter Angabe der maßgeblichen Teile <sup>12</sup>	Betr. Anspruch Nr. <sup>13</sup>
P,A	IEEE TRANSACTIONS ON MAGNETICS Bd. 28, Nr. 1, Januar 1992, NEW YORK US Seiten 474 - 477, XP000258042 M.SHIBATA ET AL. 'On-Board Power Supply System of a Magnetically Levitated Vehicle' siehe das ganze Dokument ---	1
A	DE,A,2 257 773 (WEH HERBERT) 30. Mai 1974 in der Anmeldung erwähnt siehe Seite 12 - Seite 13 ---	1
A	DE,A,2 423 579 (SIEMENS AG) 27. November 1975 siehe Seite 4 - Seite 8 ---	1,6
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<sup>10</sup> Besondere Kategorien von angegebenen Veröffentlichungen:

- "A" Veröffentlichung, die den allgemeinen Stand der Technik definiert, aber nicht als besonders bedeutsam anzusehen ist
- "E" älteres Dokument, das jedoch erst am oder nach dem internationalen Anmeldedatum veröffentlicht worden ist
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- "X" Veröffentlichung von besonderer Bedeutung; die beanspruchte Erfindung kann nicht als neu oder auf erfinderischer Tätigkeit beruhend betrachtet werden
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- "Z" Veröffentlichung, die Mitglied derselben Patentfamilie ist

**IV. BESCHEINIGUNG**

Datum des Abschlusses der internationalen Recherche

01. OKTOBER 1992

Absenddatum des internationalen Recherchenberichts

27. 10. 92

Internationale Recherchenbehörde

EUROPAISCHES PATENTAMT

Unterschrift des bevollmächtigten Bediensteten

BOURBON R.

III. EINSCHLAGIGE VERÖFFENTLICHUNGEN (Fortsetzung von Blatt 2)		
Art °	Kennzeichnung der Veröffentlichung, soweit erforderlich unter Angabe der maßgeblichen Teile	Betr. Anspruch Nr.
A	<p>JOURNAL OF THE INSTITUTION OF ELECTRICAL ENGINEERS Bd. 121, Nr. 11R, November 1974, STEVENAGE GB Seiten 1224 - 1248 A.J.ELLISON ET AL. 'Surface-guided transport systems of the future' siehe Seite 1238, Absatz 5.2 siehe Seite 1240, Absatz 6 -----</p>	1

**ANHANG ZUM INTERNATIONALEN RECHERCHENBERICHT  
ÜBER DIE INTERNATIONALE PATENTANMELDUNG NR.**

EP 9201804  
SA 63096

In diesem Anhang sind die Mitglieder der Patentfamilien der im obengenannten internationalen Recherchenbericht angeführten Patentedokumente angegeben.  
Die Angaben über die Familienmitglieder entsprechen dem Stand der Datei des Europäischen Patentamts am  
Diese Angaben dienen nur zur Unterrichtung und erfolgen ohne Gewähr.

01/10/92

Im Recherchenbericht angeführtes Patentedokument	Datum der Veröffentlichung	Mitglied(er) der Patentfamilie	Datum der Veröffentlichung
DE-A-2257773	30-05-74	Keine	
DE-A-2423579	27-11-75	Keine	

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Für nähere Einzelheiten zu diesem Anhang : siehe Amtsblatt des Europäischen Patentamts, Nr.12/82